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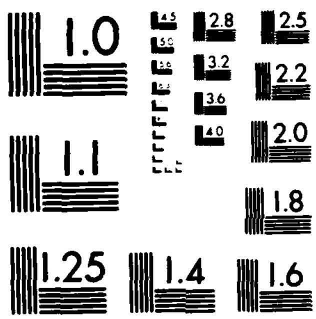

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This report describes benthic macroinvertebrate composition and distribution in four aquatic habitat types within a 60-mile reach of the Lower Mississippi River. The macroinvertebrate biotas of the four habitat types, dike fields (three), a natural bank, a secondary channel, and an abandoned channel, were studied over one high flow (flood stage), two moderate, and two low flow periods between April 1979 and September 1980.

(Continued)

20. ABSTRACT (Continued).

The biotas present in the natural bank, secondary channel, and abandoned channel showed only minor changes in composition over the various flow regimes. The natural bank was consistently dominated (numerically) by the burrowing mayflies *Tortopus incertus* and *Pentagenia vittigera* and hydropsychid caddisflies. The consistently most common taxa in the secondary channel were the sand-dwelling chironomids *Robackia claviger* and *Chernovskiia orbicus*. Phantom midges, tubificid oligochaetes, and fingernail clams were always the most abundant macroinvertebrates in the abandoned channel. Macroinvertebrate densities were always high in the mud-bottomed abandoned channel and were always low in the strong current, sandy substrate habitat of the secondary channel.

Unlike the other habitats, the dike fields showed large changes in biotic composition, which correlated with changes in river stage and resultant alterations in current and substrate. With decreased river stages current velocity was greatly reduced in each of the dike fields and substrate dominance changed from erosional (sand and gravel) to depositional (silt). Consequently, the dike field macroinvertebrate communities, which were intermediate in biotic similarities between the communities in the secondary channel and the abandoned channel at high and moderate flows, showed marked similarities at low flows to the macroinvertebrate community present in the slack-water, mud-bottomed abandoned channel. This study indicates that the distribution of macroinvertebrates in the Lower Mississippi River habitats is a function of the physical characteristics of the system, notably current velocity and substrate composition.

PREFACE

This study was sponsored by the Office, Chief of Engineers (OCE), U. S. Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Units VA, Environmental Impact of Selected Channel Alignment and Bank and Revetment Alternatives in Waterways, and VII.B, Waterway Field Studies. The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Mr. John Bushman, and Mr. James L. Gottesman. The EWQOS Program has been assigned to the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL).

This report documents the distribution and abundance of benthic macroinvertebrates associated with four different habitat types found within the main-line levees along the Lower Mississippi River. Macroinvertebrates were collected from the river between miles 506 and 566 during April 1979 through September 1980.

This report was prepared by Dr. David C. Beckett, Messrs. C. Rex Bingham, Larry G. Sanders, and David B. Mathis, and Ms. Eva M. McLemore, all of EL. This study was conducted under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group; Mr. Bob O. Benn, Chief, Environmental Systems Division; Dr. Jerome L. Mahloch, Program Manager, EWQOS; and Dr. John Harrison, Chief, EL.

Special appreciation is expressed to Mr. Stephen P. Cobb who helped plan this study and Drs. Michael P. Farrell and A. Dale Magoun, all formerly of EL, who assisted with the data analyses.

Commanders and Directors of WES during the study and the preparation of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms

BENTHIC MACROINVERTEBRATES OF SELECTED AQUATIC HABITATS OF THE LOWER MISSISSIPPI RIVER

PART I: INTRODUCTION

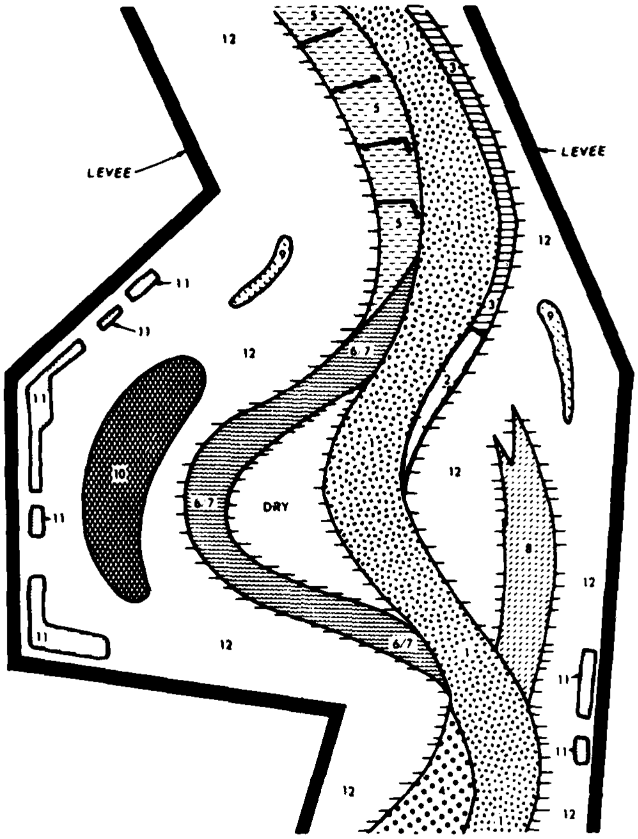
1. This investigation is part of the Environmental and Water Quality Operational Studies (EWQOS) program sponsored by the Office, Chief of Engineers, and managed by the U. S. Army Engineer Waterways Experiment Station. The objectives of the EWQOS Waterway Field Studies (VIIB), of which this study is a part, are to provide data on how control structures for channel alignment, channel straightening, and bank stabilization affect waterway ecology, and to develop environmental quality design criteria for these project features. Such river control structures are found in navigable rivers in various parts of the United States, and are especially common in the Mississippi River and its tributaries. This report describes benthic macroinvertebrate composition and distribution in aquatic habitats within a 60-mile* reach of the Lower Mississippi River and is one in an EWQOS series dealing with the aquatic habitats and biota of the Lower Mississippi River.

Study Background

2. A wide array of lotic and lentic habitats, including 14 distinct habitat types, is present within the 60-mile study area (Figure 1, Table 1). A description of these habitat types is presented in Appendix A to this report. These habitats are most distinct at low flow periods since at high flows most or all of the area between the levees may be inundated. Surface area proportions among the various habitats vary, then, as function of river stage (Table 1).

3. A pilot study of benthic macroinvertebrate communities in the study area was conducted at moderate river flows on 19-27 June 1978

* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page 3.



LEGEND

1 MAIN CHANNEL
2 NATURAL STEEP BANK
3 REVETMENT
4 SANDBARS (NATURAL)
5 DIKE FIELD
6 PERMANENT SECONDARY CHANNEL
7 TEMPORARY SECONDARY CHANNEL
8 ABANDONED RIVER CHANNEL I
9 ABANDONED RIVER CHANNEL II
10 OXBOW LAKE
11 BORROW PIT
12 INUNDATED FLOODPLAIN

Figure 1. Schematic drawing of aquatic habitats within study area in the Lower Mississippi River

(Mathis et al. 1981). Habitats studied included dike fields and dike field structures, revetted banks, natural banks, main channel, secondary channels, and abandoned channels. This pilot study showed three habitats within the study area which possessed very distinct benthic macroinvertebrate assemblages:

a. Abandoned channels characterized by a lentic assemblage composed primarily of oligochaetes, dipteran larvae, and fingernail clams.

b. Natural banks characterized by a lotic assemblage composed of burrowing mayflies and hydropsychid caddisflies.

c. Dike structures dominated by rheophilic hydropsychid caddisflies, clinging mayflies, and chironomid larvae (discussed in detail in Mathis, Bingham, and Sanders (1982)).

The other habitats sampled (dike fields, revetted banks, and main and secondary channels) were characterized by patchy sediments with the predominant number of macroinvertebrates present in microdepositional zones.

4. From information gathered in the pilot study, four habitat types were chosen for intensive study over high, moderate, and low flow conditions. Selected sampling areas included dike fields (three), a natural bank habitat, a secondary channel, and an abandoned channel. Three dike fields were chosen for study due to the physical heterogeneity exhibited among dike fields (e.g. dikes notched versus unnotched, deep versus shallow dike field pools, occurrence of pool isolation at different river stages, etc.). Two of the selected dike fields and their biotas were studied in previous Lower Mississippi River investigations (Mathis et al. 1981, Pennington et al. 1980). The third dike field (Chicot) had a notched dike and was included in the study to determine the effects of dike notching on dike field macroinvertebrates. The particular natural bank, secondary channel, and abandoned channel selected for study are typical of such habitats in the Lower Mississippi River. These sites were also included in earlier ecological investigations of the Lower Mississippi River (Miller 1981, Cobb and Clark 1981, Mathis et al. 1981, Pennington et al. 1980, Schramm and Pennington 1981). Specific objectives of the study discussed herein include:

a. Characterizing the various habitats in terms of their macroinvertebrate composition, including a comparison of results from this study's sampling at moderate flow with the results of the pilot study.

b. Comparing communities among the study habitats in terms of species composition and macroinvertebrate densities.

c. Determining to what extent the habitats' species compositions change with variations in river stage.

d. Determining the effect of Corps of Engineers constructions such as dike fields on macroinverebrate distribution and densities.

Overview of Lower Mississippi River EWQOS Reports

5. Early reports identified and characterized aquatic habitats (both natural and man-made) within the Lower Mississippi River study area (Miller 1981, Cobb and Clark 1981). Following the characterization of aquatic habitats, pilot studies investigated various aspects of the ecology of benthic invertebrates (Mathis et al. 1981), larval fishes (Schramm and Pennington 1981), and adult fishes (Pennington et al. 1980) in the Lower Mississippi River. Additional studies in the same study area dealt with macroinvertebrate drift (Bingham, Cobb, and Magoun 1980) and the assessment of macroinvertebrate colonization of stone dikes (Mathis, Bingham, and Sanders 1982). The pilot studies were summarized by Wright (1982).

6. Following the completion of the pilot studies, intensive studies regarding benthic macroinvertebrates (this report), larval fishes, adult fishes, and water quality of the Lower Mississippi River were conducted (companion reports regarding each of these topics will be published later, along with a synthesis of their findings). Because the geographic applicability of Lower Mississippi River studies is not known, verification studies are being carried out on the Arkansas and Willamette Rivers, with additional work planned on two other large, navigable rivers.

PART II: STUDY AREA

7. The study area encompasses a 60-mile reach of the Lower Mississippi River (river miles 506-566 above Head of Passes), near Greenville, Miss. The study area was laterally confined to the river's floodplain (2-6 miles wide) by main-line levees constructed by the U. S. Army Corps of Engineers. No tributaries enter this section of the Mississippi River. However, many backwater areas such as abandoned channels, borrow pits, sloughs, and oxbow lakes lie within the restricted floodplain and are occasionally contiguous with the river (especially at high flows). The study area contains a variety of natural habitats, e.g. clay banks, sandbars, permanent and temporary secondary channels, and abandoned channels. Other habitats, constructed by the Corps of Engineers, include revetted banks and dike fields containing variously designed stone dikes.

8. River stages, as measured on the Vicksburg, Miss., gauge, have varied yearly as much as 60 ft; however, during this study, river stage had a yearly maximum range of approximately 35 ft (Figure 2). Main channel water velocity is usually between 3 and 6 ft/sec with a maximum recorded velocity of 15 ft/sec. Highest discharges generally occur from February through March with lowest discharges from July through October.

9. The six sites chosen for this study (Figure 3) include three dike fields (Lower Cracraft, Leota, and Chicot Landing), a natural bank area (Anconia Natural Bank), a permanent secondary channel (American Cutoff), and an abandoned channel (Matthews Bend). Dike field refers to the areas of water (and river bottom) immediately preceding the upstream dike, between the dikes, and immediately following the downstream dike. The dike structures themselves, and their concomitant invertebrate taxa, have been analyzed in Mathis, Bingham, and Sanders (1982) and are therefore not discussed in this report. The six study areas are discussed in more detail below.

Lower Cracraft Dike Field

10. Lower Cracraft Dike Field (DFC) (river miles 506.5-511.0)

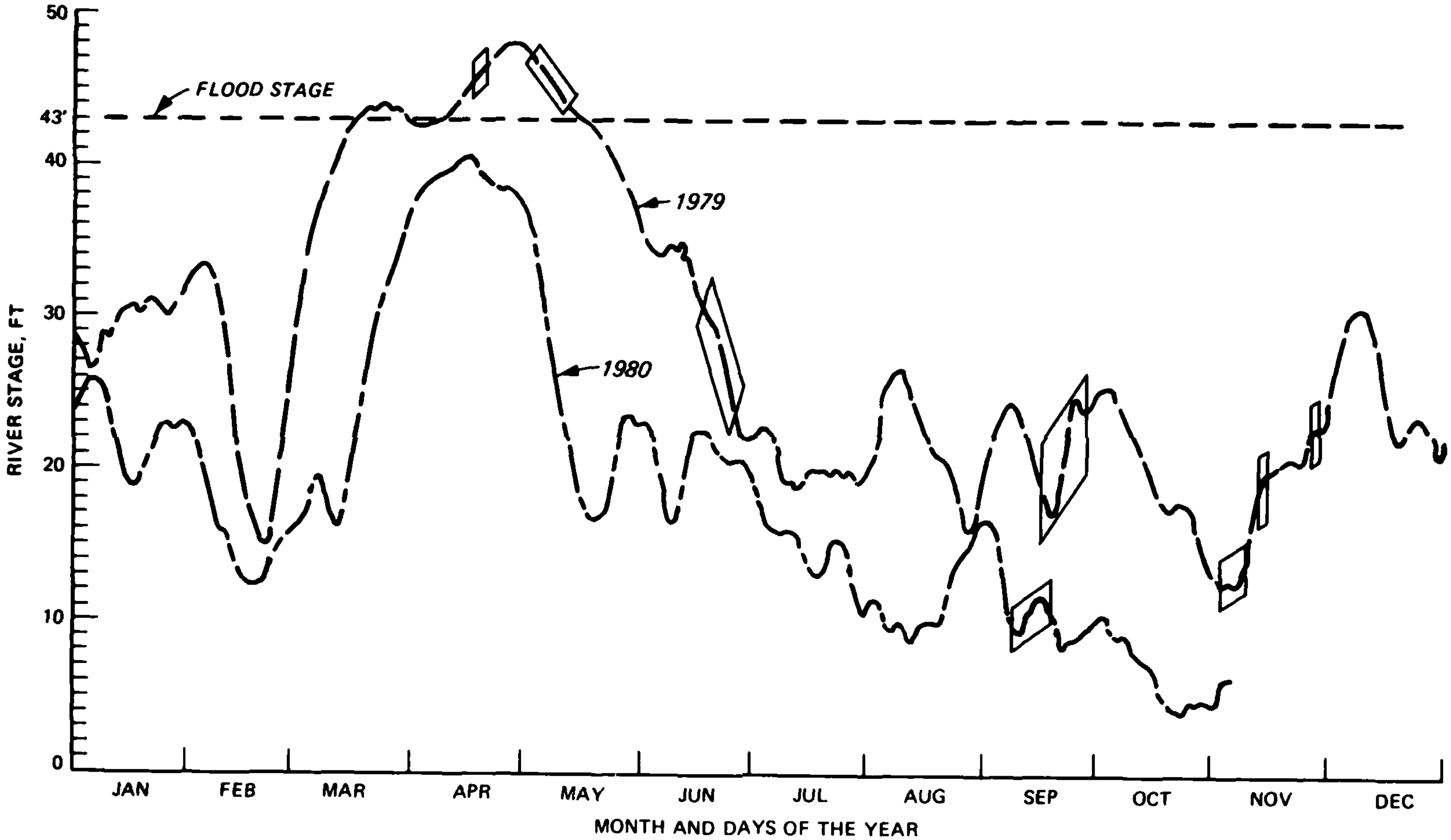


Figure 2. Mississippi River stage in 1979 and 1980. Sampling periods over 1979-1980 are indicated by the parallelograms along the stage readings. Readings taken at the Vicksburg, Miss., gauge

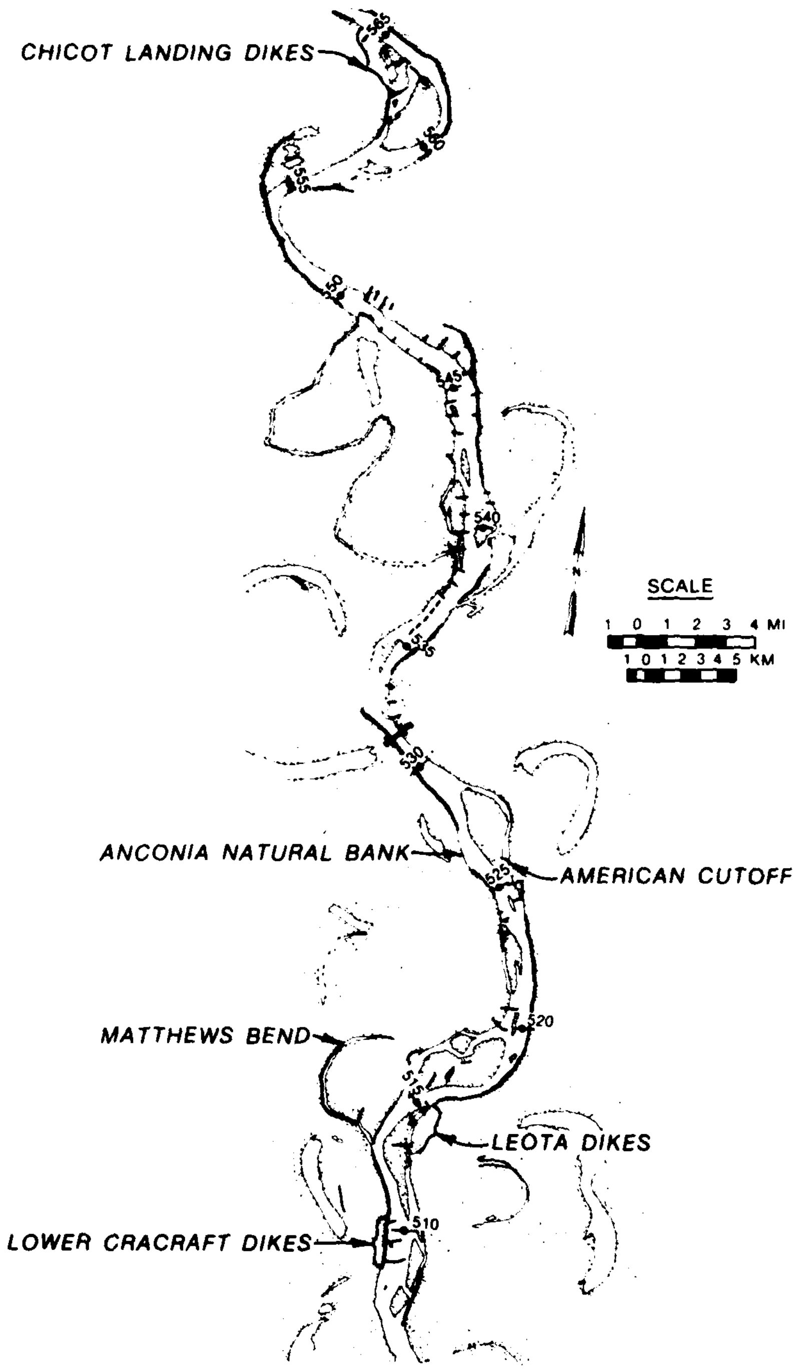


Figure 3. Study area with sampling sites identified

consists of three transverse stone dikes constructed for the dual purpose of secondary channel closure and point bar stabilization (Figure 4). Extensive sand and gravel middle bars occur between succeeding dikes and over a 3-mile reach of river downstream from the third dike. These middle bars, the main axis of which is parallel to the main channel flow, isolate extensive pools from main channel flow during low river discharge periods, confining the dike field pools between the dikes, the river bank, and the middle bars. Scour holes that are deep relative to the remaining pool exist downstream of each dike. The pool below Dike 3 (furthest downstream dike) is deep along its entire length relative to the other two pools. Isolated areas of willow trees occur on the middle bars. Substrate types within the pools vary from mud to coarse sand and gravel depending upon river stage.

Leota Dike Field

11. Leota Dike Field (DFL) (river miles 511.5-515.5) consists of three transverse stone dikes built in 1968 for the dual purposes of secondary channel closure and point bar stabilization (Figure 5). An extensive sand and gravel middle bar extends downstream from Dike 1 to approximately 1.5 miles below Dike 3. Extreme sedimentation downstream of each dike has resulted in shallow water with mostly sand and gravel substrates overlain with mud and silt at lower river stages. There are no large scour holes below the dikes in this dike field. Isolated areas of vegetation, primarily small willow and cottonwood trees, occur on the middle bar.

Chicot Landing Dike Field

12. Chicot Landing Dike Field (DFT) (river miles 562.0-565.5) was constructed in 1967-1969 to divert secondary channel flow from behind Choctaw Bar (Figure 6). The original structure consisted of three transverse stone dikes and a series of three vane dikes downstream from the last transverse dike. Since original construction, the third dike

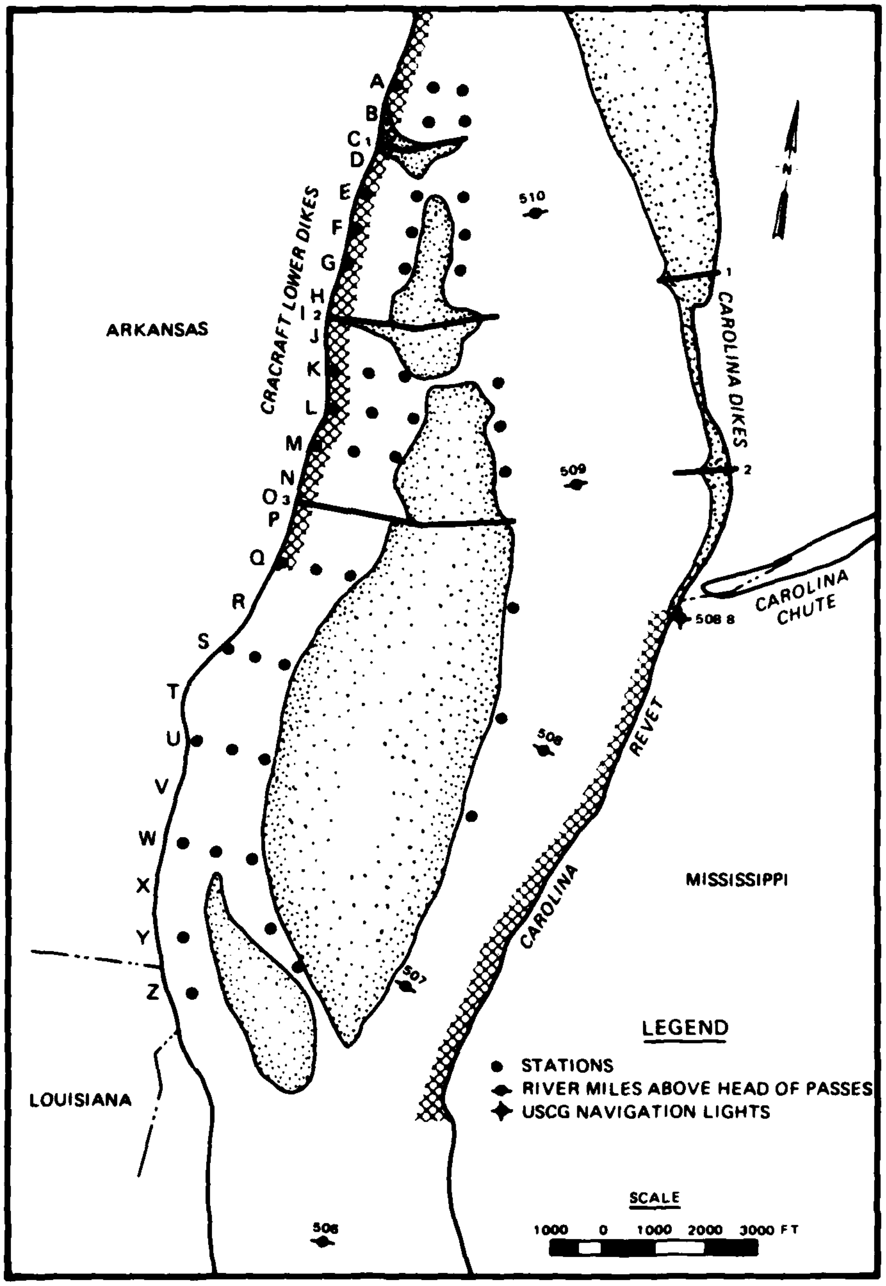


Figure 4. Lower Cracraft Dike Field (DFC) sampling site. General sampling areas are indicated by the fields of solid circles (formerly emergent middle bar areas were included in sampling at high flow). Sampling was done along transects from shore; these transects are identified by the capital letters shown along the shoreline (USCG = U. S. Coast Guard)

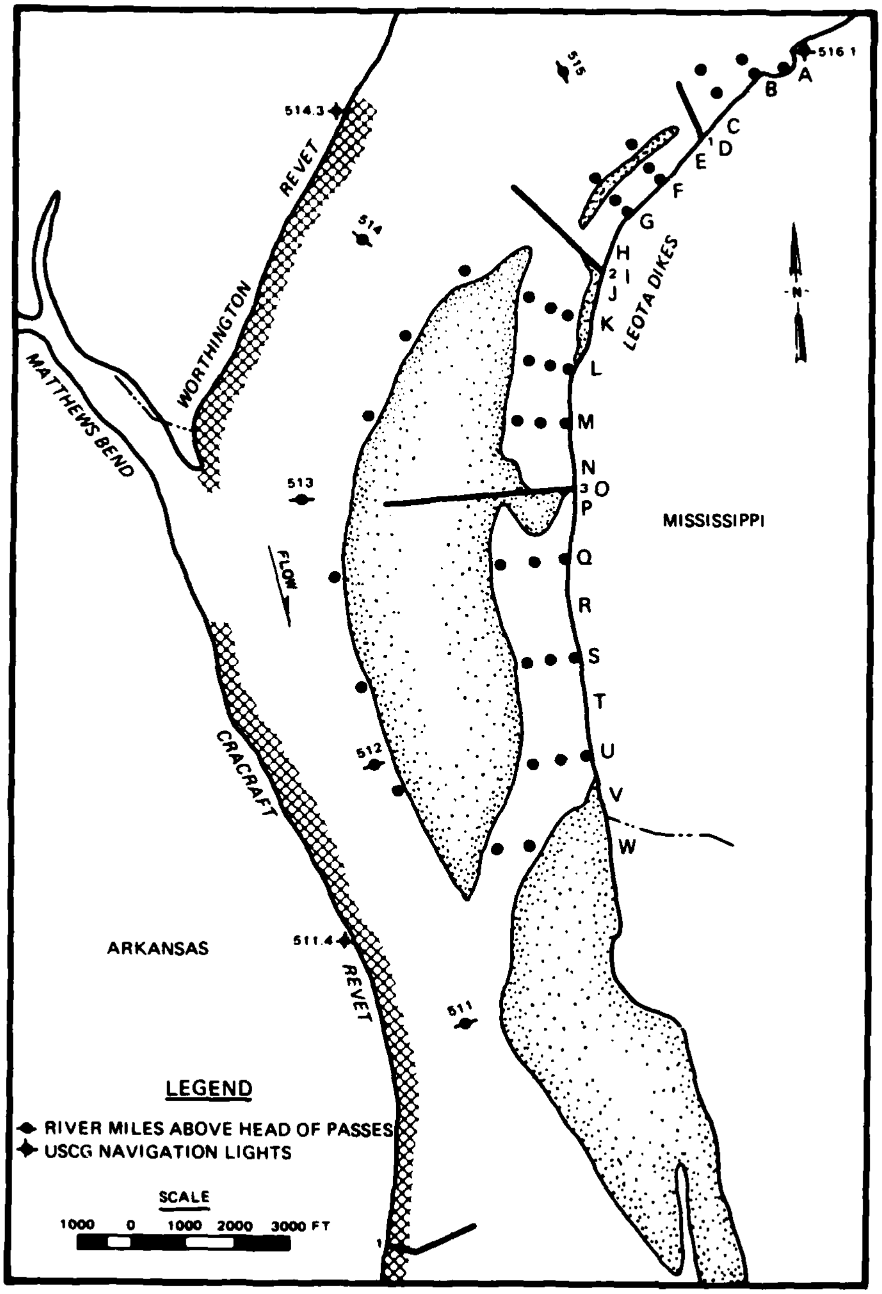


Figure 5. Leota Dike Field (DFL) sampling site. General sampling areas are indicated by the fields of solid circles (formerly emergent middle bar areas were included in sampling at high flow). Sampling was done along transects from shore; these transects are identified by the capital letters shown along the shoreline

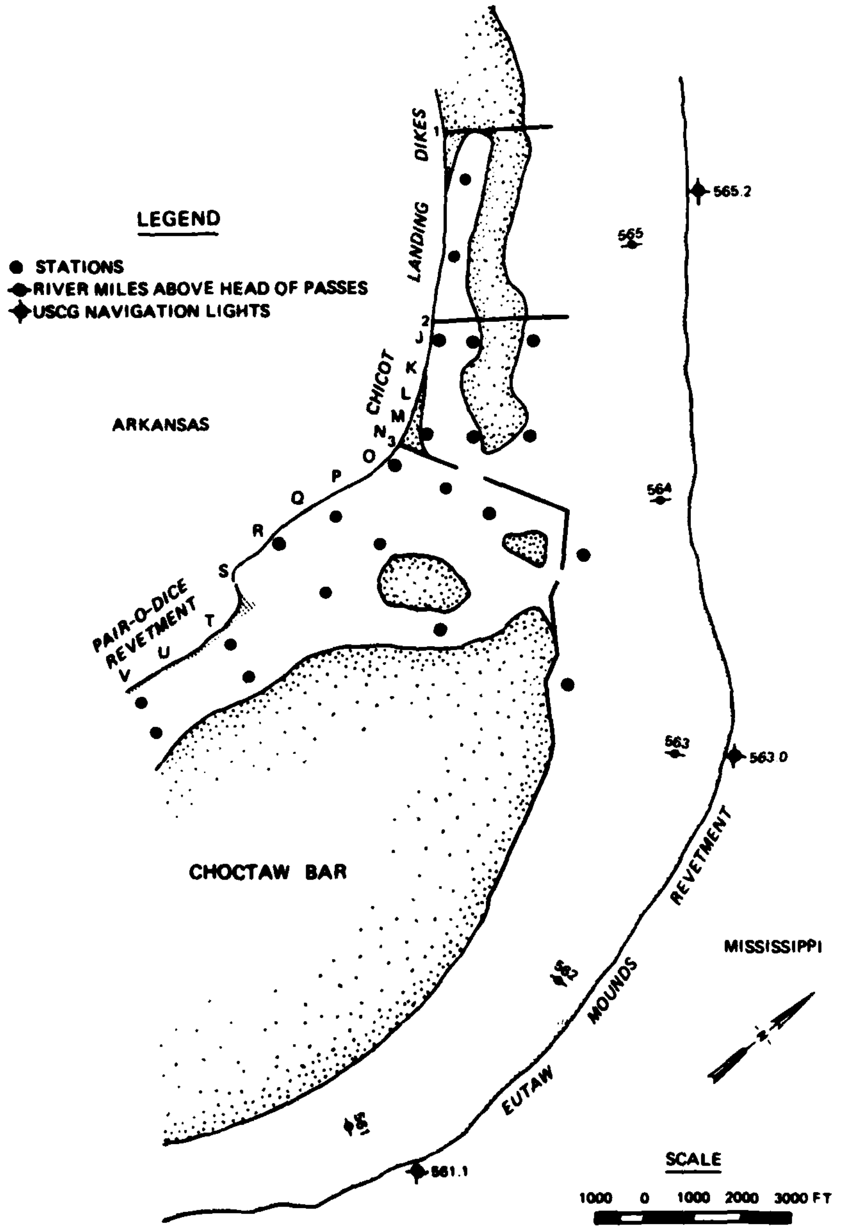


Figure 6. Chicot Landing Dike Field (DFT) sampling site. General sampling areas are indicated by the fields of solid circles (formerly emergent middle bar areas were included in sampling at high flow). Sampling was done along transects from shore; these transects are identified by the capital letters shown along the shoreline

has suffered a breach failure. In 1975 the vane dikes were connected to the third dike and extended downstream so that the third dike is now a large L-head dike with a notch in each leg of the L (Figure 6). The area of the dike field above the first dike is almost entirely silted in and was not sampled in any of our field efforts. The pools below Dikes 1 and 2 exhibit very little or no flow at low river stages. They are separated from the main channel at all but the lower end of Pool 2 by a sandbar. The secondary channel (Pool 3) below Dike 3 is separated from the main channel by the long leg of the L-head dike and Choctaw Bar.

Anconia Natural Bank

13. Anconia Natural Bank (NBA - Natural Bank at Anconia) (river miles 526.0-527.3) is an unprotected (nonrevetted) river bank along the main channel (Figure 7). The bank is steep (slope usually greater than 30 percent) and is composed of clays interspersed with sand layers. Fallen trees and snags are generally common and present an additional substrate (along with the bank itself) for macroinvertebrate colonization.

American Cutoff

14. American Cutoff (PCA - Permanent Channel, American Cutoff) (river miles 525.2-528.3) is a permanent (year-round flow maintained) secondary channel (Figure 7). Although the secondary channels are subordinate to the main channel in terms of flow-carrying capacity, environmental conditions are very similar to those of the main channel. Substrates in this area are typically coarse sand although depositional areas are present along certain stretches of the east-bank side.

Matthews Bend

15. Matthews Bend (ACB - Abandoned Channel, Matthews Bend) (contiguous with the river at river mile 513.0) is an abandoned river channel (Figure 8). Measured at low water from its confluence with the

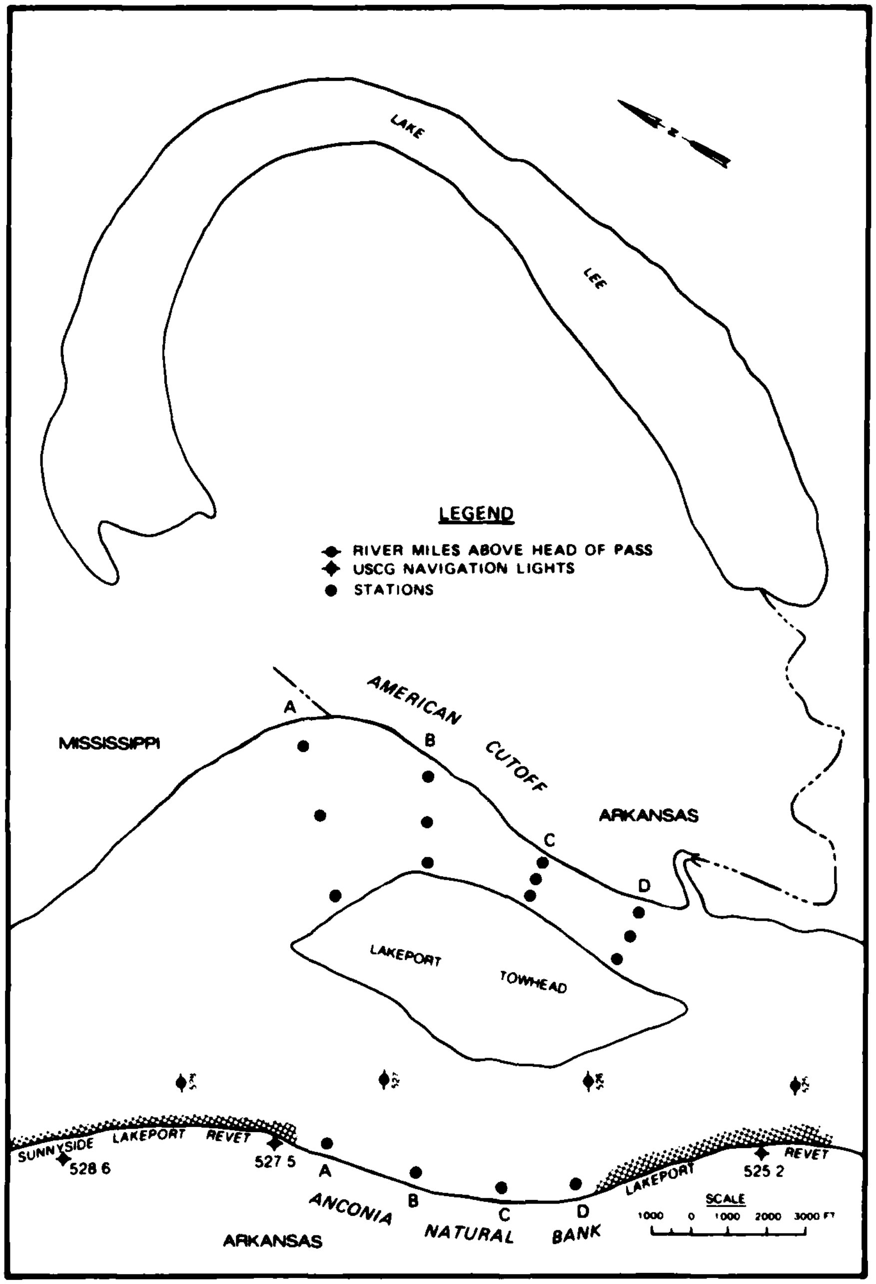


Figure 7. Anconia Natural Bank (NBA) and American Cutoff (PCA) sampling sites. General sampling areas are indicated by the fields of solid circles. Sampling was done along transects from shore; these transects are identified by the capital letters shown along the shoreline

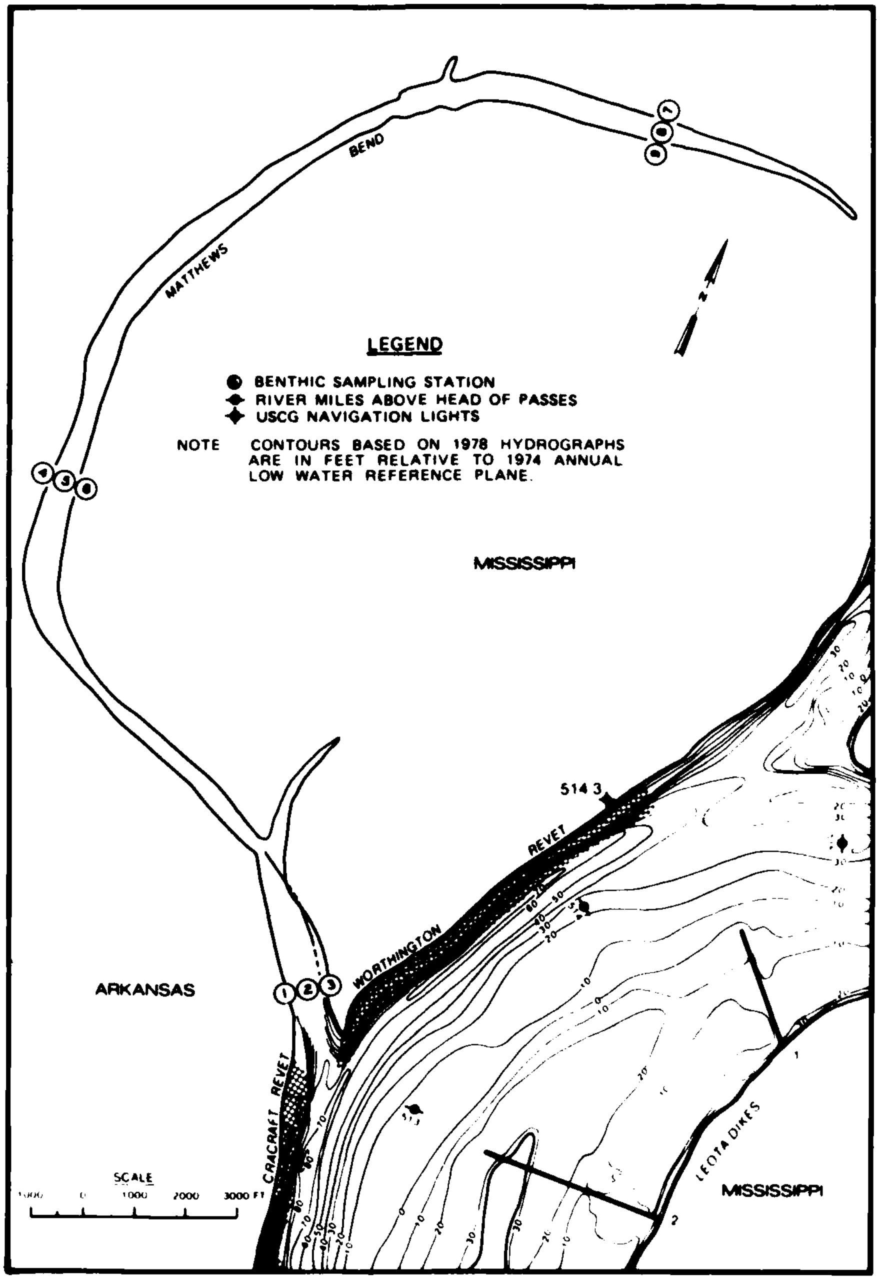


Figure 8. Matthews Bend (ACB) sampling site. Sampling stations are shown by the encircled numbers

main channel to its head, Matthews Bend is approximately 5 miles long with depth increasing downstream. At high flows some water from the river enters upstream and moves through the channel creating some current. At moderate and low flows, however, the entire area is a backwater. This area has a mud substrate during all flow conditions.

PART III: METHODS

Sampling Methods

16. Optimally, field investigations should use a single sampling gear and a single sampling design; however, the diverse habitat conditions encountered within this study area precluded such a sampling program. Conditions ranged from the backwater mud substrates of Matthews Bend (ACB) to the strong currents and shifting sand substrates of American Cutoff (PCA). At high flows the dikes and middle bars of the dike fields were completely submerged with the dike field pools completely contiguous with the main channel flow. In contrast, at low flows many of the dike field pools were completely isolated from the river, being circumscribed by the dikes, the shore, and the middle bars which rose to heights of 15 ft above the water level and could be miles long. It was decided, therefore, to use the best sampling gear and sampling design for the conditions encountered. Two grab samplers, a Shipek and a Petite Ponar, were used to sample benthic invertebrates, while two sampling designs, stratified-random and systematic, were employed.

17. The Ponar grab (Figure 9) is one of the most widely used grab samplers and is capable of efficiently sampling a wide variety of substrates (Powers and Robertson 1967). Consequently, it has become the most widely used sampling device in intensive Great Lakes (Lake Michigan) research (see Mozley and Howmiller 1977). However, the Ponar does not work well in the strong current habitats of the Mississippi River because:

- a. Incomplete jaw closure often occurs when sampling hard substrates such as coarse sand, gravel, or cohesive clay substrates.
- b. Instability occurs on steep inclines in swift water due to the sampler's high center of gravity, resulting in tip over and roll of the sampler when the bottom is contacted.
- c. High currents create a drag on the sampler lead line moving the sampler downstream of its drop point and often prevent triggering.

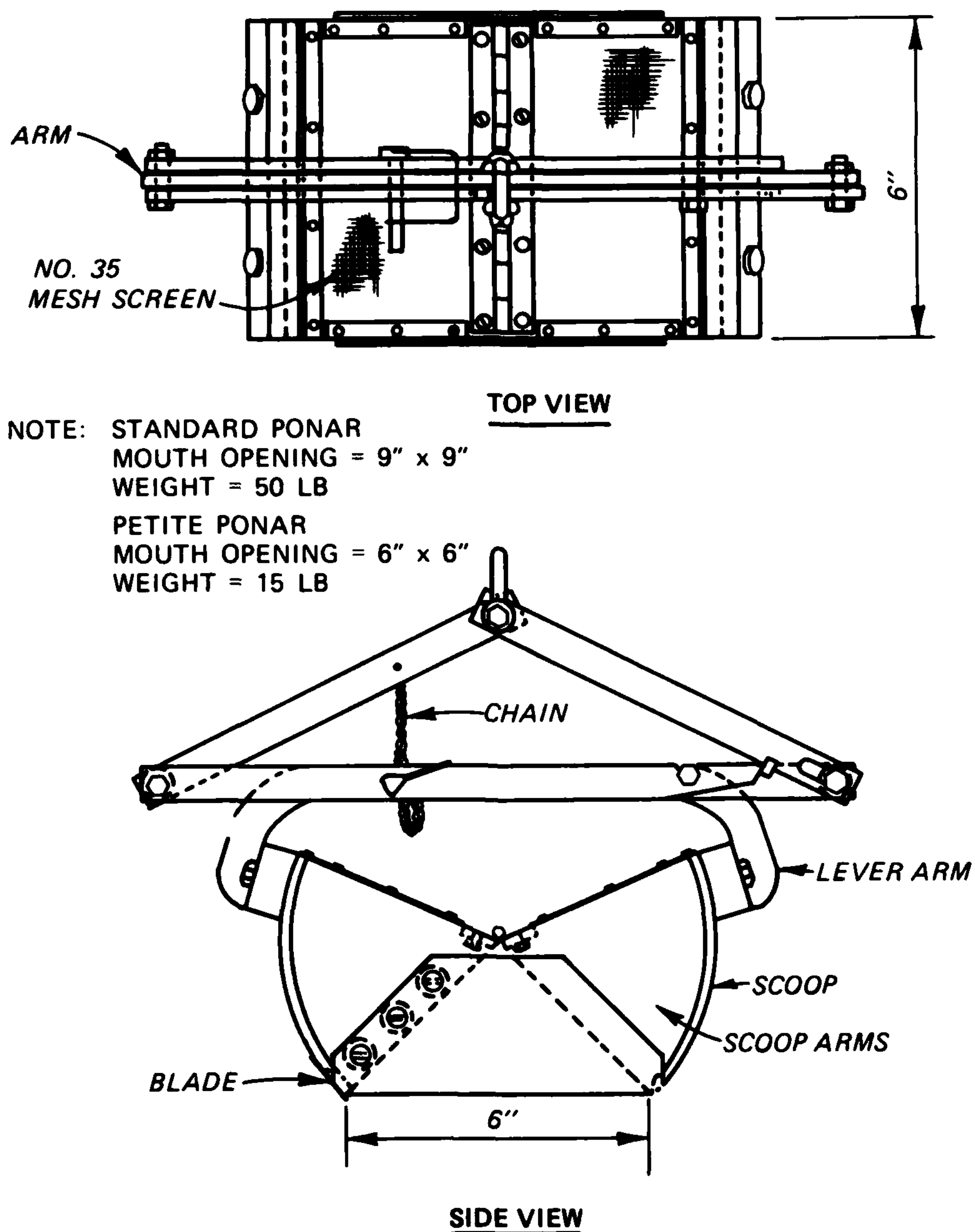


Figure 9. Ponar grab sampler (Petite Ponar shown)

18. The Petite Ponar grab was therefore used only in low current areas in which a fairly soft depositional substrate was present. Such habitats included the abandoned channel (ACB) for all sampling dates and the dike field pools at low flow conditions. The Petite Ponar, with a weight of 15 lb and a 6- by 6-in. mouth opening, was used rather than the Standard Ponar (weight of 50 lb and 9- by 9-in. mouth opening) to decrease the time required for laboratory processing of the grab samples (the decrease in area sampled per grab with the Petite Ponar rather than the Standard Ponar results in lesser numbers of animals collected). The Petite Ponar was used in soft sediments, rather than the Shipek, because the shock wave (hydraulic disturbance) that occurs when a sampler is lowered onto a substrate is less with a Ponar than the Shipek. This shock wave often blows away surface sediments and their benthos (see Brinkhurst, Chua, and Batoosingh 1969).

19. The Shipek grab sampler (Figure 10), with its spring-assisted jaw closing action and heavy weight (134 lb), has the advantage of being able to take a sample from gravel, sand, or hard consolidated sediments (clay). This sampler was used in areas where a strong current existed (dike fields at high and moderate flows, PCA during all flow conditions) and in areas where a fairly hard clay substrate occurred (NBA). The sampling bucket has an 8- by 8-in. opening. The Shipek was lowered slowly to minimize shock wave effect. Sampler type for each sampling date and location is summarized in Table 2.

20. Two common sampling designs are systematic-transect sampling and stratified sampling. The systematic-transect design consists of sampling at equal intervals along a number of transects within a habitat. This type of sampling is usually employed in habitats where sediment type is fairly uniform. In this study, ACB, NBA, PCA, and DFT were sampled using the systematic-transect design at all river stages.

21. Stratified sampling is usually employed in habitats in which the bottom is mosaiclike consisting of a variety of substrates (sand, gravel, mud, clay, etc.) present in very different proportions. With this sampling design the habitats' substrates are sampled and mapped before benthic samples are taken. Various points within each habitat

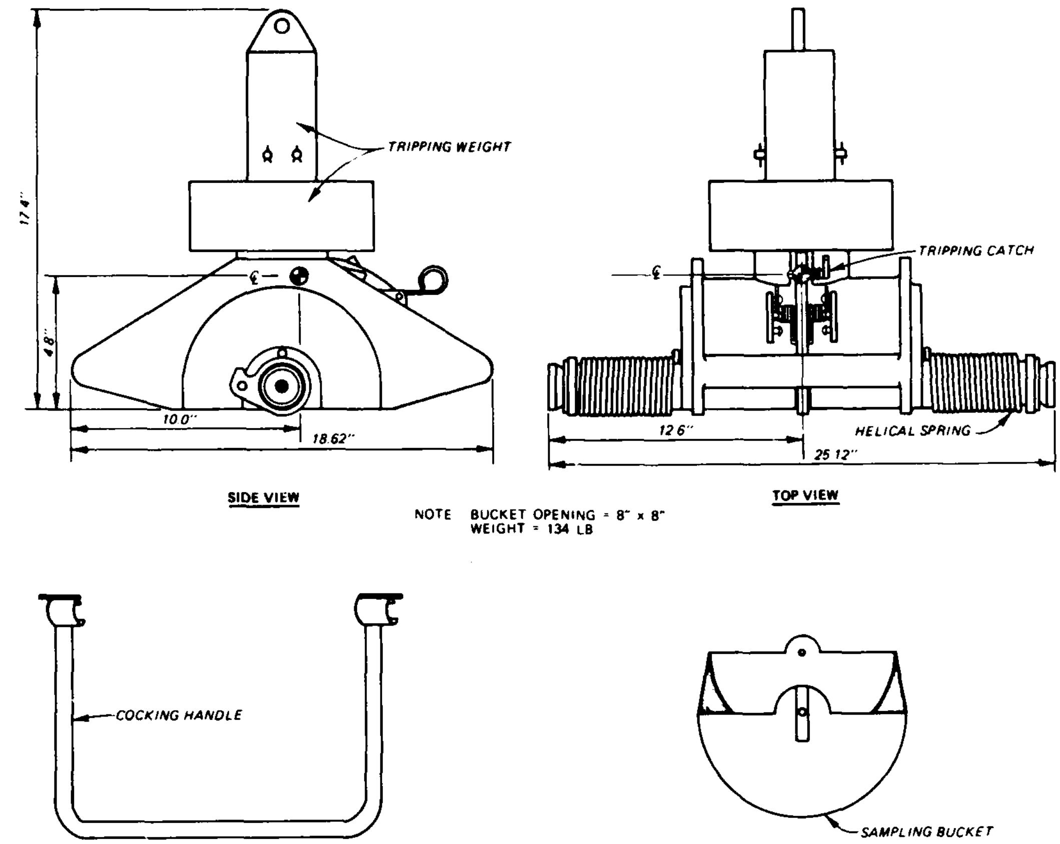


Figure 10. Shipek grab sampler

are then selected for benthic sampling with productive substrates sampled proportionately more often than their occurrence in the habitat. Hence, more sampling effort takes place in areas where greater numbers of taxa and higher total densities (and usually higher sampling variability) exist. Study areas DFC and DFL were sampled using a stratified design at high and moderate flows. Sampling design for each sampling date and location and number of grabs (one or two) per sampling station are summarized in Table 2. Regardless of whether one or two grabs were taken per station, each grab was regarded as a single entity in the data analysis, i.e., replicates were not averaged or pooled prior to analysis.

22. Sampling transects were established perpendicular to the shoreline with transect locations and sampling site stations along these

transects positioned by triangulation using a Del Norte Microwave Positioning System. The number of sampling stations along a transect was fairly constant at NBA, ACB, and PCA, but varied at the dike fields since a large portion of most of the transects was inundated only at higher river stages.

23. A visual classification of sediment type was made with each grab sample based upon general sediment classification such as sand and gravel, sand alone, mud, mud mixed with sand, and clay (for particle size classification see Appendix B). Grab samples were sieved in the field using a U. S. Standard No. 35 mesh screen (openings = 500 μ). Macroinvertebrate samples were preserved in the field with 10 percent buffered formalin. In the laboratory, samples were hand sorted at 3X magnification into major taxonomic groupings, and transferred to a 70 percent ethanol solution. Oligochaetes were transferred to a lactophenol clearing solution for at least 5 days prior to identification to aid in taxonomic identification. Macroinvertebrates were identified to the lowest possible taxonomic level.

Analytical Methods

24. Proportional abundance of the substrate types per habitat per date (Table 3) was compiled from the visual sediment classification data gathered at the time of benthic sampling (for systematic-transect sampling) and from the substrate mapping data collected shortly before benthic sampling in the case of stratified sampling. Since macroinvertebrate distribution is often patchy and dependent on substrate type, macroinvertebrate densities (Tables 4-9) are presented as invertebrate densities per major substrate type. All grab sample data were standardized to numbers per square metre prior to data analysis.

25. A summary table (Table 10) shows the three most dominant (by number) taxa collected from each of the habitats. Since this table is a compilation of macroinvertebrates over all the substrates sampled within each habitat, it can be biased by a disproportionate amount of sampling in a certain substrate type. The systematic-transect design

used in the majority of the sampling gives a fairly unbiased estimate of substrate types; i.e., substrate types are sampled in close proportion to their actual occurrence in the habitat. Stratified sampling (used at DFL and DFC at high and moderate flows, Table 2) involved a disproportionate amount of sampling in mud substrates, and numbers in Table 10 for DFC and DFL in April-May and June may be biased in favor of those animals occurring in mud substrates. Stratified sampling efforts are marked with an asterisk in Table 10 and the reader can refer to Tables 4 and 5 for a breakdown of macroinvertebrate densities by substrate type for these occasions.

26. An important portion of this study involved measuring the relatedness among the biotic communities present in the studied habitats. A similarity index was used to determine the relatedness, or similarities, between the macroinvertebrate communities. One of the simplest and most widely used means of measuring this relative similarity between communities is the coefficient of community (Whittaker 1975), which measures similarities in terms of species presence or absence. The particular coefficient of community used in this study was Jaccard's coefficient. This index has been used by Whittaker and Fairbanks (1958); Cairns and Kaesler (1969, 1971); Cairns, Ruthven, and Kaesler (1974); Roback, Cairns, and Kaesler (1969); Hocutt et al. (1974); Crossman, Kaesler, and Cairns (1974); Kaesler, Cairns, and Bates (1971); and Kaesler and Cairns (1972) in determining similarities among sampling sites for studies involving freshwater taxa. The Jaccard coefficient S_j can be expressed in the following manner: $S_j = a/(a + b + c)$. In comparing two sample sites, a = number of species common to both sample sites; b = number of species found at Site 1 but not at Site 2; and c = number of species found at Site 2 but not at Site 1. Since it is a pair-wise comparison, all possible combinations are made. Jaccard's coefficient values range from 0.00 (complete dissimilarity) to 1.00 (complete similarity). In this study, a similarity matrix was generated for each sampling period (Tables 11-15).

27. After a similarity matrix is formed, an interpretation of the data is made and/or the data are subjected to further analysis using

ordination or cluster analysis. Ordination is a form of indirect gradient analysis (Whittaker 1975) and provides a graphical summary of the similarity between samples, stations, or communities. This technique was introduced by Bray and Curtis (1957) and is commonly called Wisconsin comparative or polar ordination.

28. An ordinational diagram (Figure 11--Part IV: Results) was developed for each sampling period from its respective similarity matrix. The ordinational diagram is generated by:

a. Picking a pair-wise comparison from the similarity matrix that has very low similarities. These two sampling sites, showing the low similarities, form the pair of endpoints for an axis.

b. Each of the other sampling sites is compared to each of these endpoints, and is located somewhere along the axis on the basis of relative similarities to the two endpoints. Calculation of location on the axis is based on the Pythagorean theorem and uses the formula $x = L^2 + D_1^2 + D_2^2 \quad 2L$. D_1 , D_2 , and L are the decimal (or percent) dissimilarity values, equal to 1.00 minus the similarity value (from the similarity matrix). L is the dissimilarity between the two endpoints; D_1 is the "distance" or dissimilarity of a sampling site from the first endpoint; D_2 is that sampling site's dissimilarity from the other endpoint. The location of the sampling site on the axis is equal to x .

c. A pair of sampling sites that are located near the middle of the axis but which show little similarity in the similarity matrix are selected as endpoints for a second axis and sampling sites are located on the second axis in the same manner as their location on the first axis.

d. All communities, or sampling sites, therefore, have an x- and y-location on a two-dimensional graph. Generally, those points which are located near each other in the ordinational diagram are biotically similar. Points located far apart on the ordinational diagram have little similarity in terms of the species present at their sampling locations. Ordinational diagrams for this study are presented in Figure 11. Further details concerning the computation and use of ordination can be found in Cottam, Goff, and Whittaker (1973) and Whittaker (1975). Ordination has been used in studies of freshwater macroinvertebrate communities by Burlington (1962), Beckett (1978), Culp and Davies (1980), Gore (1980), and Simpson (1980).

PART IV: RESULTS

Organization of Section

29. In this Part, results from each study site are presented across the complete range of flow conditions (sampling trips) with a brief summary of trends and changes in that particular habitat. A comparison is then made among the habitats for each flow condition, comparing the habitats' macroinvertebrate communities on the basis of their relative biotic similarities.

Lower Cracraft Dike Field - DFC

May 1979

30. Lower Cracraft Dike Field substrates were predominantly sand and sand mixed with gravel when sampled on 4, 7, and 8 May 1979 (Table 3). At this high flow period, these erosional substrates made up 84 percent (by area) of the bottom substrates. Sampled with a stratified design, the dominant (by number) organisms collected (Table 10) were tubificid oligochaetes, including *Limnodrilus* sp. (immatures), *Limnodrilus cervix*, and *Ilyodrilus templetoni* (immature worms of the genus *Limnodrilus* can be identified only to the generic level).

31. Mean macroinvertebrate density was lower in the sand and sand mixed with gravel substrates (116.5 macroinvertebrates/m^2) than mean density in mud and mud mixed with sand (680.6 macroinvertebrates/m^2) (Table 4). Although densities in mud were higher than those in sand and gravel, macroinvertebrate numbers in the mud substrates were relatively low in comparison to densities in mud substrates at other sites sampled during the same flow condition (ACB for example), and were also low in comparison to mean densities at DFC during low flow conditions.

32. Although *Limnodrilus* immatures were the dominant taxa in both the erosional (sand and gravel) and depositional (mud) substrates at DFC, the chironomid *Chernovskiia orbicus* was the second most common

macroinvertebrate in the erosional substrates while *L. cervix* was the second most common macroinvertebrate in the mud (Table 4). *Chernovskiia orbicus* has been collected by other investigators from sandy areas of large rivers in the United States and the USSR (Saether 1977). A total of seventeen taxa were collected at DFC in the May sampling.

June 1979

33. Sampling in the moderate flows occurring on 22, 24, and 25 June 1979 again showed a lower mean density in the sand and gravel substrates (78.0 macroinvertebrates/m^2) than that of the mud substrates (440.0 macroinvertebrates/m^2) (Table 4). Thirty taxa were collected at DFC in this sampling effort. Sand and sand mixed with gravel were again the predominant substrates totaling 91 percent of the bottom area (Table 3).

34. A compilation of the dominant organisms within the substrate types present in the dike field (Table 4) shows marked substrate preferences among the collected macroinvertebrate species. The two dominant invertebrates in the erosional substrates were the chironomids *Robackia claviger* and *Polypedilum* sp. As in the case of *C. orbicus*, *R. claviger* lives in sandy substrates of large rivers in the United States and the USSR (Saether 1977). Mud substrates were dominated by *Limnodrilus* immatures and the burrowing mayfly, *Pentagenia vittigera*. Dominant organisms in the clay included the hydropsychid caddisfly *Potamyia flava*, the introduced clam species *Corbicula fluminea*, and a burrowing mayfly species, *Tortopus incertus* (Table 4). It is probable that *P. flava*, one of the dominant hydropsychid caddisflies in large rivers of the eastern United States (Wiggins 1977), had colonized objects on the clay substrate rather than the clay itself. Densities were relatively low in all substrate types.

September 1979

35. Densities remained relatively low in DFC during the 26 and 27 September 1979 moderate flow sampling (Table 4). A breakdown of substrate types present shows an increase in area of depositional substrates and subsequent decrease in erosional substrate areas (Table 3). *Limnodrilus* spp., including *L. cervix* and *Limnodrilus* immatures, again

dominated the mud substrates. The burrowing ephemerid mayfly *Hexagenia* sp. was also found in fairly high numbers in the dike field's mud substrates on this date (*Hexagenia* sp. discussed in this report refers to *H. limbata* and/or *H. bilineata*; characters used to differentiate these two species at the nymphal stage have proved to be unreliable - Edmunds, Jensen, and Berner 1976).

36. Sand substrates were dominated by the Asiatic clam, *C. fluminea*, and the sand-dwelling chironomid species *R. claviger* (*R. claviger* was also the dominant macroinvertebrate collected in the sand substrates of DFC in the June sampling) (Table 4). Only one sample was collected from a clay substrate; the two dominant organisms in the clay were the mayfly *P. vittigera* and the oligochaete *L. cervix*. Twenty taxa were collected from DFC in September 1979.

November 1979

37. Mean macroinvertebrate density in the mud substrates collected on 6 and 7 November 1979 was the highest among the samplings to date. *Limnodrilus* immatures were the taxon collected in the highest numbers in the mud while the phantom midge *Chaoborus punctipennis* and the burrowing mayfly *Hexagenia* sp. were also present in relatively high numbers (Table 4). Mean density in sand substrates was much lower than that of the mud (147.2 macroinvertebrates/m^2 versus 1328.6 macroinvertebrates/m^2) with sandy substrates having *C. fluminea* and *Limnodrilus* immatures as the most numerous taxa. Thirty-five taxa were collected from DFC during this sampling effort. The relative area covered by depositional substrates continued to be markedly higher than the values of the May and June samplings (Table 3) due to the isolation of the dike field pools at low flow with a resultant marked decrease in current and deposition of previously suspended materials.

September 1980

38. Sampling on 9 September 1980, a low flow period for the Mississippi River, showed a higher mean macroinvertebrate density in the mud than any other sampling trip (Table 4). In addition to supporting high numbers of macroinvertebrates, mud and mud mixed with sand made up the overwhelming majority (totaling 92 percent) of the bottom

area in the dike field pools (Table 3). The two most common taxa collected in the mud substrates were *Limnodrilus* immatures and the chironomid *Chironomus* sp. (Table 4). Sand and gravel areas were dominated by two chironomid genera, *Polypedilum* sp. and *Chironomus* sp. Forty-three taxa were collected from DFC at this time, the highest number of taxa collected among the samplings at this site.

DFC summary

39. Sand and sand mixed with gravel areas supported lesser numbers of macroinvertebrates than respective mud substrates for each sampling date. At higher flows, erosional substrates were numerically dominated by *C. orbicus* and *R. claviger*, two chironomid species that show a marked preference for sandy areas in rivers. Mud substrates were dominated at all flows by *Limnodrilus* immatures, with mature *L. cervix* present in large numbers for all sampling dates. *Hexagenia* sp. was also quite common in mud samples in September and November 1979. The two low flow sampling efforts (November 1979 and September 1980) showed the highest numbers of taxa collected and the highest mean densities in mud substrates.

Leota Dike Field - DFL

May 1979

40. Substrates in Leota Dike Field during the benthic sampling of 3 and 4 May 1979 were almost wholly sand or sand mixed with gravel (totaling 95 percent of the bottom area) (Table 3). Numbers of macroinvertebrates per area in these substrates were quite low (mean density = 22.8 macroinvertebrates/m^2) with the two most numerous taxa being the dipteran (family Heleidae) *Bezzia* sp. and the sand-dwelling chironomid species *R. claviger* (Table 5). Only one benthic sample was obtained from both mud substrates and clay substrates due to the paucity of these substrates in the dike field. Both of these samples were dominated by hydropsychid caddisflies (*Hydropsyche* sp. and *P. flava*). These caddisflies probably occurred on hard substrates (rocks and twigs) occurring within or on the mud or clay. Fifteen taxa were collected from DFL in May.

June 1979

41. Although flows were moderate during 25 and 29 June, rather than the high flows of May, sand and sand mixed with gravel were still the overwhelmingly dominant substrate types, totaling 96 percent of the bottom area (Table 3). Due to the stratified sampling design, a fairly large number of samples (18) were taken from mud substrates, showing an interesting macroinvertebrate distribution among substrates within the dike field. Sandy substrates were dominated by *P. flava* and, again, *R. claviger* (Table 5). Immature oligochaetes (*Limnodrilus* sp.) dominated mud areas while the burrowing mayfly *T. incertus* was the most numerous macroinvertebrate in clay substrates. *Tortopus* spp. have been described as being fairly specific for clay substrates in large rivers (Edmunds, Jensen, and Berner 1976). Twenty-four taxa were collected from DFL in June.

November 1979

42. Benthic results from the low flow samples of DFL taken on 5 and 6 November 1979 presented a striking parallel with November 1979 DFC results. As in the case of DFC, *C. fluminea* and *Limnodrilus* immatures were the dominant taxa in the sandy substrates. Mean macroinvertebrate density in the mud substrates showed the highest value to date (1671.2 macroinvertebrates/m^2) in DFL (as did DFC in November - Table 4), with *Limnodrilus* immatures and *Chironomus* sp. the most prevalent species. The highest number of taxa collected (thirty) to date in DFL was obtained in this sampling.

September 1980

43. Forty-eight taxa were collected from DFL in the low flow sampling of 10 and 11 September 1980; this was the highest number of taxa collected over all DFL sampling efforts. Mean density in the mud substrates was also the highest value to date (4518.6 macroinvertebrates/m^2). Mud and mud mixed with sand were the predominant (totaling 68 percent) substrate types in the isolated dike field pools existent at this low flow period (Table 3). *Limnodrilus* immatures and the chironomid *Tanypus* sp. were the dominant invertebrates in the mud substrates while the tubificid oligochaete *Aulodrilus pigueti* and

Limnodrilus immatures were the most common taxa encountered in sand and gravel substrates (Table 5).

DFL summary

44. Substrates in DFL were predominantly sand and sand mixed with gravel at high and moderate flow sampling periods with mud and mud mixed with sand dominating at low flows. Macroinvertebrate densities were low in both sand and mud substrates at higher flows with the hydropsychid caddisflies *Hydropsyche* sp. and *P. flava* among the most common macroinvertebrates collected at these times. The chironomid species *R. claviger* was one of the dominant macroinvertebrates in sandy substrates during high and moderate samplings (it was also a dominant at DFC at these times). With decreased flow, mean macroinvertebrate densities increased in the mud substrates as did the total number of taxa collected for DFL as a whole. The lowest flow sampling, September 1980, showed the highest mean densities for both sand and mud substrates and had the highest number of taxa collected among the DFL samplings.

Chicot Landing Dike Field - DFT

May 1979

45. Densities in the erosional substrates (sand and sand mixed with gravel) (mean density = 31.2 macroinvertebrates/m^2) were much lower than densities in mud substrates (mean density = 2663.4 macroinvertebrates/m^2) in the high flow sampling of 11 May 1979 (Table 6). *Limnodrilus* immatures and *L. cervix* were the dominant macroinvertebrates collected in mud substrates while *Limnodrilus* immatures and the chironomid *C. orbicus* were the two most common invertebrates collected in erosional substrates. Mean density in the mud stubstrates was higher than that of DFL and DFC for the sampling period. Sand was the predominant substrate type during this high flow condition (Table 3). Sixteen taxa were collected from DFT during this sampling.

June 1979

46. Mean macroinvertebrate density in mud (2167.1 macroinvertebrates/m^2) was again much higher than collections in sandy substrates

(101.0 macroinvertebrates/m^2) (Table 6). *Limnodrilus* immatures were the most numerous taxon collected in both of these substrate types with *Limnodrilus hoffmeisteri* the second most common species in mud substrates. Twenty-three taxa were collected in the moderate flow sampling of 28 June.

September 1979

47. While *Limnodrilus* immatures were the dominant invertebrate taxon in DFT (as a whole) on 28 September (Table 10), analysis by substrate type again showed a sharp contrast in macroinvertebrate dominance among the substrates. Mud substrates were dominated, as usual, by the tubificid oligochaetes, *Limnodrilus* immatures and *L. cervix*, with *Hexagenia* sp. the third most common macroinvertebrate (Table 6). The most common invertebrate in sandy areas was the sand-dwelling chironomid *C. orbicus*. Bottom samples from clay substrates were dominated by the mayfly species *T. incertus* and *P. vittigera*. Forty-one taxa were collected from DFT on the 28 September sampling.

November 1979

48. With low river flows on the 13 November sampling date, mud and mud mixed with sand became the dominant substrates totaling 75 percent of the bottom area (Table 3). Sand and sand mixed with gravel substrates continued to support only low numbers of macroinvertebrates (mean density = 64.6 macroinvertebrates/m^2) with the chironomid *C. orbicus* being the most common invertebrate collected in such areas. Two tubificid taxa, *Limnodrilus* immatures and *I. templetoni*, were the two most common taxa collected in mud substrates, while the burrowing mayfly, *Hexagenia* sp., ranked third. Forty-two taxa were collected at DFT during this sampling effort.

September 1980

49. The highest number of taxa collected at DFT throughout the study was in September 1980 (51 taxa). Mud substrates continued to show greater densities (mean density = 2805.6 macroinvertebrates/m^2) than sand (mean density = 582.8 macroinvertebrates/m^2) with *Limnodrilus* immatures and the phantom midge *C. punctipennis* most common in the mud. The Asiatic clam, *C. fluminea*, and the chironomid species *R. claviger*

were the most common organisms in sandy substrates.

DFT summary

50. Total taxa values showed an inverse relationship with river discharge with 16 taxa collected at high flow and 42 and 51 taxa collected at the low flows of November 1979 and September 1980, respectively. Mud substrates consistently supported greater numbers than sandy areas with tubificid oligochaetes the most common macroinvertebrates encountered in mud bottom areas. *Hexagenia* sp. was also present in fairly high numbers in mud substrates in September and November 1979. Sandy areas were characterized by low densities throughout the sampling with *Limnodrilus* immatures, *C. fluminea*, and the sand-specific chironomid species *C. orbicus* and *R. claviger* most common. The few clay samples collected contained predominantly *P. vittigera* and *T. incertus*.

Anconia Natural Bank - NBA

May 1979

51. Clay and clay mixed with sand were the dominant substrate types (totaling 70 percent of the substrate) at Anconia Natural Bank on 5 May 1979 (clay and clayey mixtures were dominant substrates at this site throughout the study - Table 3). Macroinvertebrate densities were low in both sand (mean density = 121.1 macroinvertebrates/m^2) and clay (mean density = 62.2 macroinvertebrates/m^2) (Table 7). The burrowing, large-river mayfly *P. vittigera* was the most common organism in both substrates. Nineteen taxa were collected from NBA in this high flow sampling.

June 1979

52. Macroinvertebrate densities were very low in sandy substrates in June (mean density = 12.1 macroinvertebrates/m^2) with mean density in clay equal to 437.3 macroinvertebrates/m^2. The mayfly *T. incertus* was the most common organism in clay. The caddisfly *Hydropsyche* sp. was also fairly common in clay substrate areas as was *P. vittigera*. Eighteen taxa were collected at NBA in the moderate flow sampling of 26 June.

September 1979

53. Low macroinvertebrate densities were again apparent in samples from sandy areas of NBA in the moderate flow sampling period of 20, 24, and 28 September (Table 7). The burrowing mayfly species *P. vittigera* and *T. incertus* were the most common taxa collected, both in sand and in the more prevalent clay substrate. Twenty-three taxa were collected during the sampling.

November 1979

54. Densities were low in both sand and clay substrates in the low flow 29 November sampling. Most common among the animals present were the euryhaline amphipod, *Corophium* sp., and the mayfly *P. vittigera* (Tables 7 and 10). Twelve taxa were collected at this site during the November sampling.

September 1980

55. Sandy area samples were dominated by hydropsychid caddisflies (*Hydropsyche* sp. and *P. flava*). It is probable that these caddisflies colonized substrates such as submerged tree branches (which are fairly common at NBA) located over the sand rather than the sand itself. The caddisfly larvae were collected in the Shipek as they were scraped off the branches by the sampler during descent. Dominant organisms in the clay included *P. vittigera* and the chironomid *Xenochironomus* sp. Twenty-two taxa were collected.

NBA summary

56. Unlike the three dike fields, no mud substrates were present at NBA. Instead, substrates were either sand or clay with clay predominant. Macroinvertebrate densities were low at NBA, especially in sandy substrates. Clay substrate areas were dominated by the burrowing mayfly species *T. incertus* and *P. vittigera*. Hydropsychid caddisflies were also fairly common at NBA on the submerged tree branches which were common in this habitat.

American Cutoff (Permanent Secondary Channel) - PCA

May 1979

57. Sand was the dominant substrate type at the permanent secondary channel at American Cutoff in the high flow sampling of 5 May (sand was the dominant substrate type at PCA throughout the study (Table 3)). Macroinvertebrate densities were low in all substrates present (Table 8). *Chernovskiia orbicus* was the most common taxa in the sandy substrates while Lumbriculid oligochaetes were the most common macroinvertebrates in mud substrates. Only six taxa were collected during this sampling.

June 1979

58. Distinctive associations between substrate type and predominant macroinvertebrate taxa were apparent in the moderate flow sampling of 19 June. The sand-specific chironomid species *R claviger* was the dominant organism in sandy substrates, with *Limnodrilus* immatures and *L. cervix* most common in mud (Table 8). The burrowing mayfly *T. incertus*, the dominant species in the clay banks of NBA, was the dominant organism in clay-bottomed areas of PCA. Densities in all substrate types remained low although the number of taxa collected increased to twenty.

September 1979

59. Sand remained the dominant (78 percent) substrate present at PCA and was inhabited chiefly by the chironomids *R. claviger* and *C. orbicus*. Densities remained low in the mud substrates present with *P. vittigera* and the amphipod *Corophium* sp. the most common organisms. Seven taxa were collected from PCA during this moderate flow sampling of 20 September.

November 1979

60. The chironomids *C. orbicus* and *R. claviger* continued to dominate sandy substrates in the 11 November sampling while *C. punctipennis* and *Limnodrilus* immatures were the most common organisms in mud and mud mixed with sand (Table 8). Densities remained low in all substrate types with thirteen taxa collected during this low flow sampling effort.

September 1980

61. Densities again remained low in all substrates with the

Asiatic clam, *C. fluminea*, and the chironomid *C. orbicus* the most common in sandy substrates. *Xenochironomus* sp., the most common species in the clay banks of NBA in September 1980, was relatively common in the mud and clay substrates of PCA on 9 September during this low flow sampling. Nine taxa were collected on this date.

PCA summary

62. Sand remained the dominant substrate in the strong current habitat of PCA throughout the various flow regimes. Densities in both the sand and other available substrates were relatively low for all samplings. The total number of taxa collected for each sampling occasion was also low in comparison to the taxa collected at the study's other habitats. Sandy areas were dominated by the chironomids *R. claviger* and *C. orbicus*, with *Limnodrilus* spp. in small numbers in the existent mud areas. The burrowing mayflies *T. incertus* and *P. vittigera* were present in low densities in mud or clay areas as were hydropsychid caddisflies.

Matthews Bend (Abandoned Channel) - ACB

April 1979

63. The abandoned channel at Matthews Bend had a slack current (even at April high flows) and a uniform substrate consisting almost entirely of mud (Table 3). Mean macroinvertebrate density was quite high during the sampling of 16 and 17 April 1978 with 6142.1 macroinvertebrates/m^2 of mud substrate (Table 9). The dominant taxa at this time consisted of the tubificid worms *I. templetoni* and *Limnodrilus* immatures (Tables 9 and 10) with a total of twenty-one taxa collected.

June 1979

64. The phantom midge *C. punctipennis* was an overwhelming dominant in ACB's benthic samples taken during 21 and 22 June 1979, a moderate flow period for the Mississippi River. *Chaoborus punctipennis* made up 57 percent (by number) of the animals collected with *Limnodrilus* immatures the second most common taxon (Tables 9 and 10). Examination of the substrate obtained in benthic samples continued to show ACB as a

mud-bottom habitat. June sampling showed a marked increase in the number of taxa at ACB (in comparison with April) with forty-one taxa collected.

September 1979

65. Sampling on 18 September 1979, again at moderate flow conditions, showed benthic composition at this date to be quite similar to that observed in June. Once again forty-one taxa were collected, with *C. punctipennis* and *Limnodrilus* immatures still the two dominant taxa (Tables 9 and 10). Macroinvertebrate densities were high at ACB during this sampling in comparison to the other habitats sampled (this pattern was consistent throughout the study).

November 1979

66. *Chaoborus punctipennis* and *Limnodrilus* immatures continued to dominate benthic collections made on 8 November 1979. Fifty-one taxa were collected on this date, the highest number collected over the length of the study. The abandoned channel's bottom substrate consisted, as usual, of predominantly mud.

September 1980

67. Although *C. punctipennis* was found in fairly large numbers in benthic grabs on 9 September 1980, the fingernail clam *Sphaerium transversum* was the most numerous taxon collected, with *Limnodrilus* immatures the second most common taxon (Table 9). Only nineteen taxa were collected on this date, showing a marked decrease in comparison to the samplings of June, September, and November 1979.

ACB summary

68. The abandoned channel is characterized, physically, at all river stages, by slack currents and a uniform mud substrate. Macroinvertebrate densities were high over all flow regimes with consistently high numbers of *C. punctipennis*, *Limnodrilus* immatures, and the fingernail clam *S. transversum*.

Comparison of Habitat Biotic Compositions: Similarity Matrices and Ordination

April-May 1979

69. The April-May (high flow) ordinational analysis of macroinvertebrate species at the study habitats showed wide compositional dissimilarities among the communities at PCA, ACB, and NBA (Figure 11). Polar ordination showed that the highest biotic similarity between any two study sites at high flow was that of the DFC - DFT comparison. An examination of the April-May similarity matrix (Table 11) also showed this pair-wise comparison to have the relatively highest similarity (0.55). In terms of quantitative representation of species, DFC and DFT were also similar. Ranking of the dominant taxa (by number) in DFC and DFT for both mud and sand/gravel substrates produced identical results (see Tables 4 and 6).

70. None of the dike fields showed affinities to the community present in the slack waters of ACB, with DFL showing the greatest dissimilarity. This dissimilarity between DFL and ACB was corroborated by the dominance of current-dependent species such as *Hydropsyche* sp., *P. flava*, and R. claviger at DFL.

June 1979

71. The ordination of the study habitats for the June moderate flow sampling (Figure 11) displayed very similar relationships to that seen in April-May. The macroinvertebrate communities in the strong currents of PCA, the slack waters of ACB, and the natural bank at Anconia (NBA) showed wide dissimilarities. The highest similarities existed in the pair-wise comparisons of the dike fields (Table 12). The community at DFL again showed the greatest dissimilarity (among the dike fields) to the macroinvertebrate community of ACB (among the dike fields DFL also showed the highest similarity to the community at PCA).

September 1979

72. The September 1979 (moderate flow) ordination (Figure 11) was quite similar to those of April-May and June (1979). The biotas at PCA, NBA, and ACB continued to be quite different (Figure 11 and Table 13). DFC and DFT were located in the ordination at an

"intermediate" position between the PCA and ACB communities.

November 1979

73. The ordination resulting from the November 1979 (low flow) benthic sampling shows that a striking change in biotic affinities had occurred (Figure 11). While ordinations from earlier samplings showed the biotic compositions at the dike fields to be generally intermediate between the PCA and ACB endpoints, sampling at the low flows of November produced an ordination in which all the dike fields showed a marked similarity to the slack-water community of ACB. In addition, all the dike fields had relatively higher similarities to each other than they had exhibited previously, as indicated by the fairly tight cluster of DFL, DFC, and DFT in November's ordination. The communities at NBA, PCA, and ACB continued to show wide dissimilarities as seen in the low similarity values in these pair-wise comparisons in the November similarity matrix (Table 14).

September 1980

74. The ordination resulting from the September 1980 low flow sampling (Figure 11) was very similar to that of November 1979 (also low flow). Sites DFC, DFL, and DFT again formed a tight cluster, indicating high biotic similarities among these study sites. All the dike fields continued to show a much greater affinity to the macroinvertebrates of ACB than to the communities present at PCA or NBA. Sites PCA, NBA, and ACB continued to show wide dissimilarities in biotic composition (Figure 11 and Table 15).

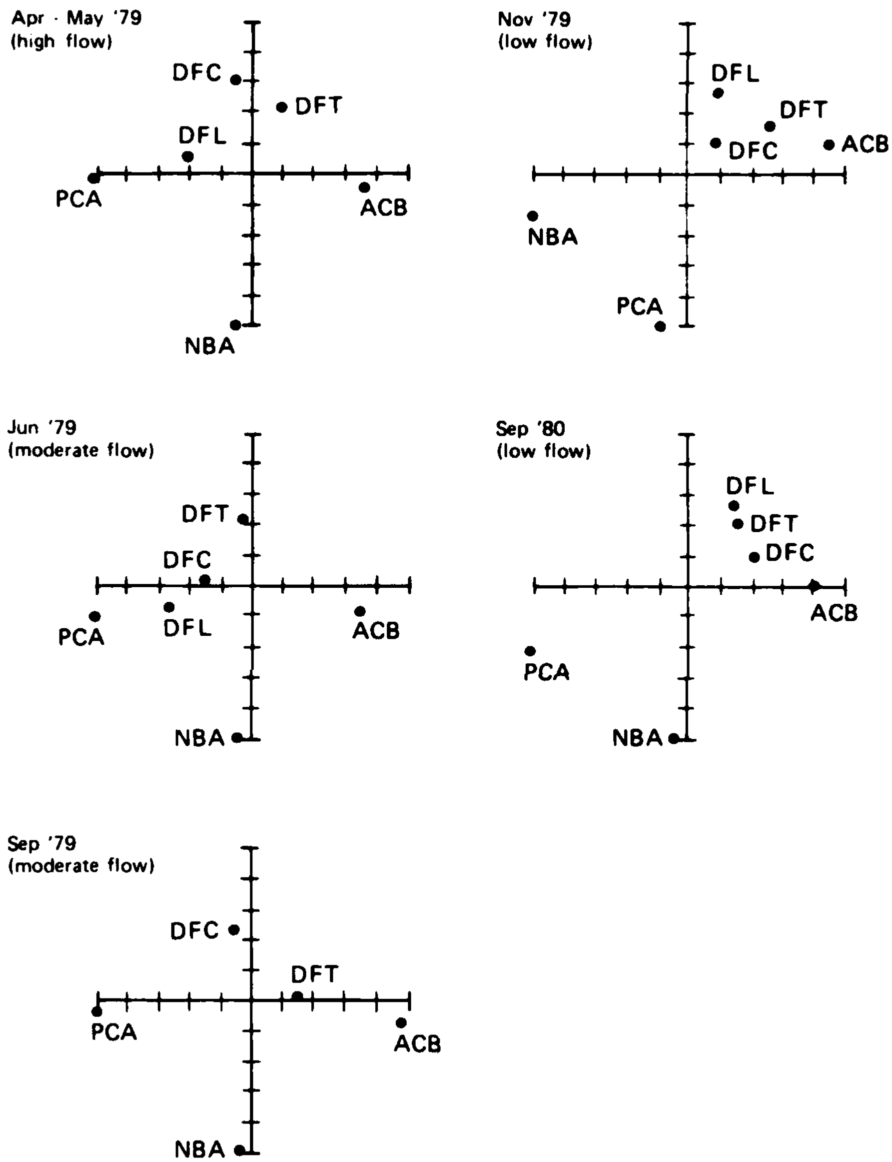


Figure 11. Two-dimensional polar ordination of study sites' macroinvertebrate communities for 1979-1980 high (one), moderate (two), and low flow (two) samplings. Distance along the axes from one cross-mark to another is equal to 10 percent dissimilarity

PART V: DISCUSSION

75. In the 1978 pilot study of macroinvertebrate distribution in Lower Mississippi River aquatic habitats, Mathis et al. (1981) found *Limnodrilus* spp. to be overall the dominant taxa in the four dike fields investigated (DFC and DFL were included in their study sites). Their investigation, at a moderate river flow period, also found *Tortopus incertus*, *Pentagenia vittigera*, and *Corbicula fluminea* to be other taxa that were found fairly frequently in the dike fields. In the present study, we also found *Limnodrilus* spp. to be a numerical dominant in the dike fields (Table 10). The majority of *Limnodrilus* spp. consisted of *Limnodrilus* immatures; mature *Limnodrilus* present consisted of *L. hoffmeisteri*, *L. cervix*, and *L. maumeensis*. *Tortopus incertus*, *P. vittigera*, and *C. fluminea* were also found frequently at the dike fields in the present study as well as in the pilot study.

76. The pilot study indicated that within the dike fields the burrowing mayfly *T. incertus* was restricted to small reaches of natural bank habitats and microdepositional zones composed of relatively firm substrates. Our breakdown of dominant organisms among substrate types within the dike fields (Tables 4-6) corroborates the finding that *T. incertus* is restricted to firm substrates. The only substrate type in the dike fields in which *T. incertus* was found to be a dominant was clay (Tables 5 and 6). In addition, *T. incertus* was found to be one of the dominant organisms in the clay banks of NBA (Table 7). Edmunds, Jensen, and Berner (1976) have also indicated that the typical habitat of *Tortopus* spp. is clay banks of large rivers.

77. Mathis et al. (1981) also indicated that, in the dike fields, *C. fluminea* was one of the few taxa encountered at sampling stations with coarse sand and gravel substrates. We also found *C. fluminea* to be common in coarse sand and gravel substrates (Tables 4-6). This clam, introduced to the United States in 1938 (Sinclair and Isom 1963), was also found in clay and mud substrates in the dike fields. It was present in its greatest densities, however, in the coarse sand and gravel substrates. Britton and Murphy (1977), in a study of Texas reservoirs,

also found *Corbicula* to be distributed across a variety of bottom types with a preference for sandy areas.

78. A pair of chironomid species, *Robackia claviger* and *Chernovskiia orbicus*, were also consistently present in the sand substrates in the dike fields (Tables 4-6). As members of the *Harnischia* complex of the Chironomidae, *C. orbicus* has been reported from sandy areas of large rivers in the USSR and the United States while *R. claviger* has been collected from a number of rivers in the United States, including the Mississippi and Missouri (Saether 1977). In the dike fields, we collected these chironomids only from sand and coarse sand and gravel substrates. These chironomid species were also the dominant organisms in the sandy substrates of PCA. We conclude, therefore, that in the Mississippi River these species are found only in existent patches of sand or sand mixed with gravel, usually in an area of strong current.

79. Densities in mud substrates in the dike fields were always higher than densities in sand and/or gravel, due largely to the large numbers of tubificid oligochaetes found in these depositional areas (Tables 4-6). Dipteran larvae, including the chironomids *Chironomus* sp. and *Tanypus* sp., and the phantom midge *Chaoborus* were also occasionally present in large numbers.

80. It is apparent from Figures 12-14 that the bottom substrates of the dike fields are mosaiclike, consisting of patches of various sediment types arranged as a function of current across the habitat. Concomitant with this mosaiclike substrate pattern is a parallel distributional pattern of macroinvertebrates. Sand and gravel areas are colonized by *C. fluminea* and the sand-dwelling chironomids *C. orbicus* and *R. claviger*; these areas have few species and the species that are present are generally found in small numbers. Mud substrates support macroinvertebrate communities characterized by relatively larger numbers of taxa found in greater densities than sand/gravel substrates; these depositional areas are dominated by tubificid species, especially *Limnodrilus* spp. Clay substrates are colonized by the burrowing mayflies *T. incertus* and *P. vittigera* with some hydropsychid caddisflies present on additional substrates (tree branches, rocks) overlaying the clay.

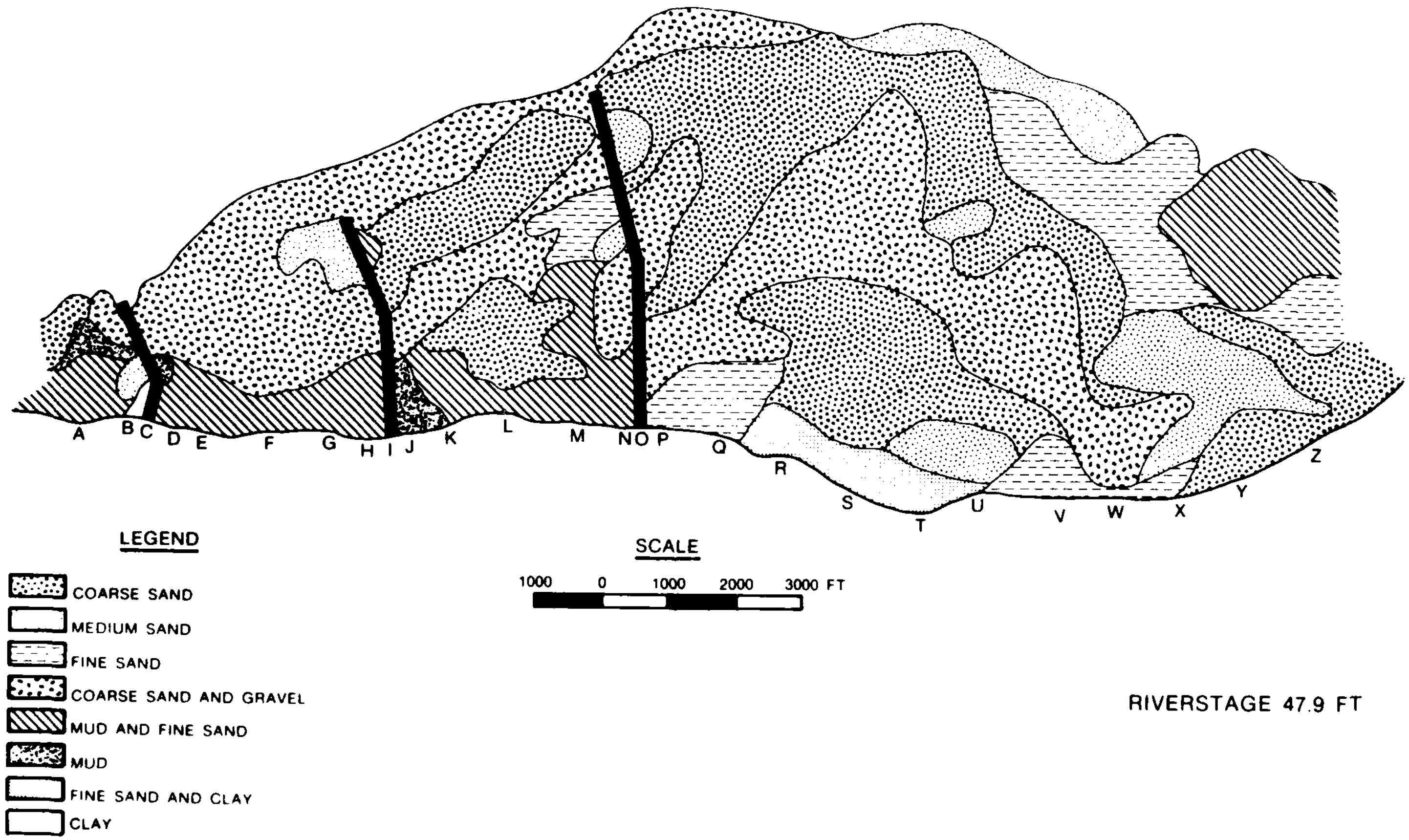


Figure 12. Substrate map of Lower Cracraft Dike Field at high flows of 26 April 1979

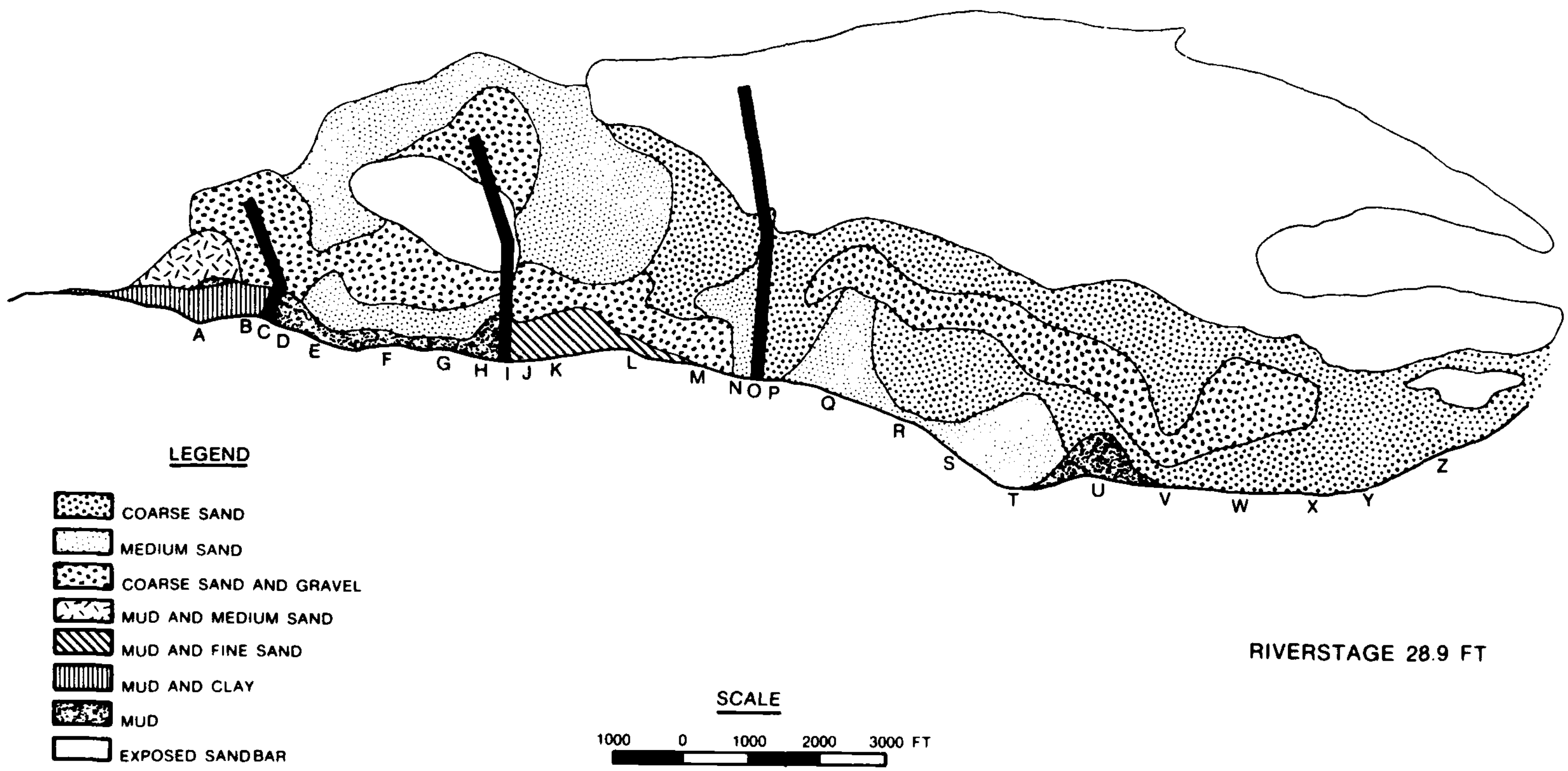


Figure 13. Substrate map of Lower Cracraft Dike Field at moderate flows of 20 June 1979

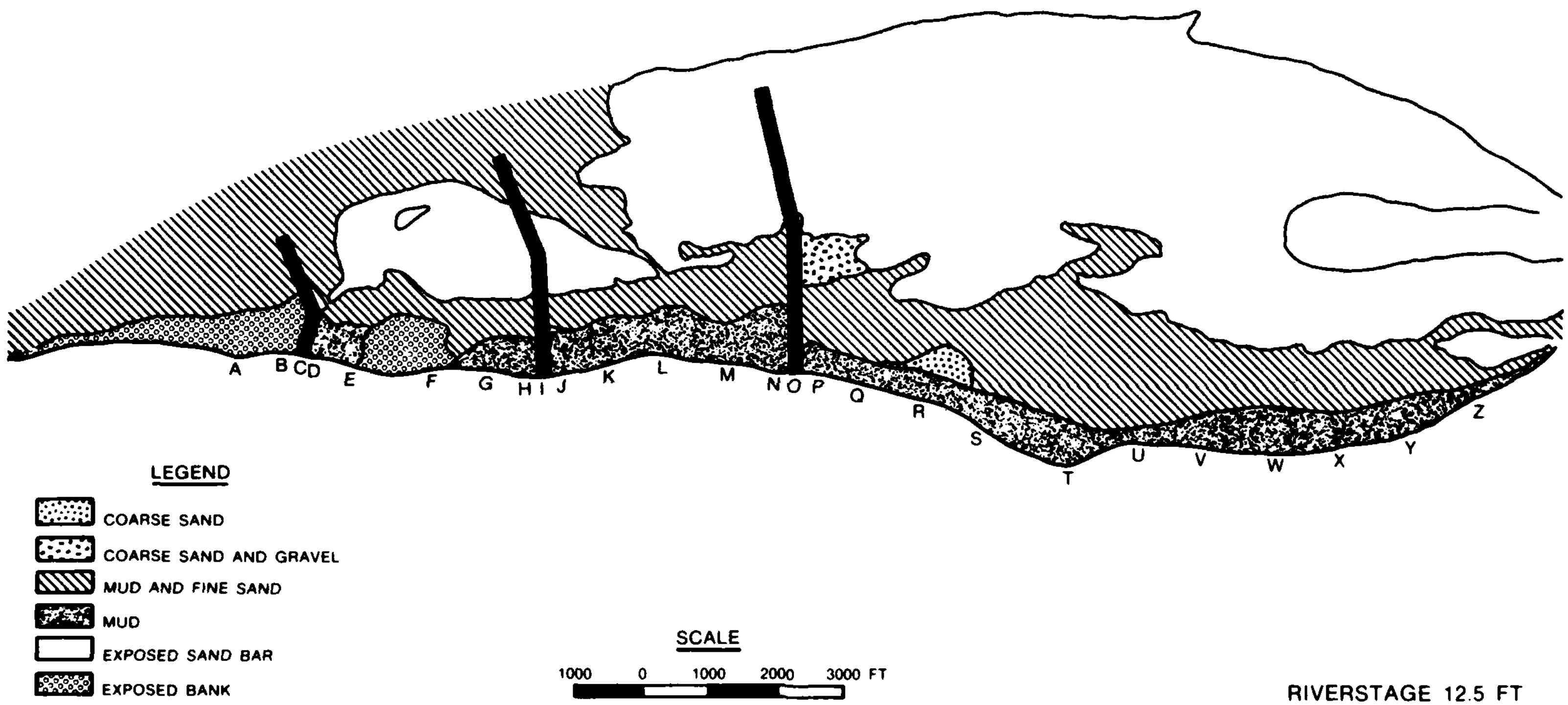


Figure 14. Substrate map of Lower Cracraft Dike Field at low flows of 6 November 1979

81. A species of special interest in this study was the burrowing mayfly *Hexagenia* sp. As a consequence of the channelization of the Lower Mississippi, current velocity has been increased resulting in decreased optimal habitat (silt bottom) and decreased numbers of *Hexagenia* (Fremling 1973). The mud substrates of the dike fields supported fairly dense *Hexagenia* populations. *Hexagenia* sp. was the third most common macroinvertebrate species in the mud substrates of DFT in September 1979 and November 1979, and, at DFC, was the second most common species in the mud substrates in November 1979 and the third most common taxa in September 1979. Therefore, although dikes are part of the channelization process, they also create habitat areas suitable for *Hexagenia*.

82. Five natural bank habitats were investigated in the 1978 pilot study, including Anconia Natural Bank (NBA)--the natural bank habitat sampled intensively in this study. Mathis et al. (1981) found that *Hydropsyche* spp., *T. incertus*, *P. vittigera*, and *P. flava* were the most common taxa in the natural bank habitat. Data from our study (Table 7) show these same taxa to be dominant in the natural bank over the various flow stages. The natural bank habitat was characterized, physically, by a predominant clay substrate at all times (Table 3). Such areas provide an optimal habitat for *T. incertus* (Edmunds, Jensen, and Berner 1976) (and also for *P. vittigera* according to our data); these clay banks often have a honeycombed appearance with the banks distinguished by very large numbers of holes resulting from the burrowing activities of these mayfly species.

83. The distribution of *T. incertus* in the investigated Mississippi River habitats provides a good example of the importance of substrate to the distribution of many macroinvertebrate species. In addition to being found in large numbers in the clay substrates of NBA, *T. incertus* was collected at DFL, DFT, and PCA. In each of these cases, however, it was collected in appreciable numbers only in clay substrates within these habitats (Tables 5, 6, and 8).

84. The permanent secondary channel (PCA), with its high current velocities and an erosional (sand) substrate at all times, provided

conditions typical not only to a permanent secondary channel but also to that of main channel erosional habitats. Not surprisingly, macroinvertebrate densities were quite low in this habitat (Table 8). Mathis et al. (1981) found PCA to be "unproductive" in the 1978 pilot study, and Hynes (1970) has indicated that in lotic systems sand is a rather poor habitat with "few specimens of few species."

85. Mathis et al. (1981) indicated that such high energy aquatic habitats are "probably unsuitable for the establishment of a distinct... macroinvertebrate community.' While our study also shows these areas to be unproductive in terms of macroinvertebrate numbers and biomass, our data also show that these areas do possess a very distinct assemblage of organisms, consisting of two sand-dwelling chironomid species, *C. orbicus* and *R. claviger*. As can be seen in Table 8, the sandy areas of PCA (the predominant substrate type) are consistently dominated by one or both of these chironomid species. Interestingly, the high current, sandy substrate areas of the dike fields investigated in the present study were also colonized by these chironomids (Tables 4-6).

86. The biota in the abandoned channel at Matthews Bend (ACB) presented a marked contrast to the macroinvertebrates of the unproductive habitat at PCA. Macroinvertebrate densities were always high in ACB (Table 9). The slack-water conditions resulted in a uniform silty bottom throughout ACB; these are typical conditions in a Mississippi River abandoned channel habitat (Mathis et al. 1981).

87. The dominant taxon at ACB, *Chaoborus punctipennis* (a phantom midge), although present in riverine habitats (Whitton 1975), is much more common and is found in greater abundances in lentic habitats such as lakes and ponds (Cole 1975, Merritt and Schlinger 1978, Pennak 1978, Reid 1961, Wetzel 1975). It is especially common in eutrophic lake and pond bottoms (Cole 1975, Reid 1961). In the moderate flow investigation of five abandoned channel habitats, *C. punctipennis* was found to be the most abundant species (Mathis et al. 1981). Pronounced oxygen depletion occurring in 1978 near the bottom of two comparatively deep abandoned channels (ACB - 1.1 mg/ℓ and Lake Lee - 1.8 mg/ℓ) apparently did not inhibit colonization of the bottom by large numbers of *Chaoborus* (Mathis

et al. 1981). *Chaoborus* has been known to survive 2 to 3 weeks in anaerobic conditions (Cole 1975) and is therefore adapted to such highly eutrophic conditions.

88. The presence of large numbers of tubificid oligochaetes, *Limnodrilus* (immatures) and *I. templetoni*, and the fingernail clam *S. transversum*, along with the previously mentioned *Chaoborus*, shows the biota at ACB to be typical of a lakelike situation rather than riverine. Reid (1961) described the profundal fauna of eutrophic lakes as consisting of "predominantly tubificid oligochaetes, bivalved mollusks of the family Sphaeriidae and dipteran insects of the genus *Chaoborus* and *Chironomus*." It is apparent that the biota at ACB closely fits this description. Species common in the various flowing water habitats investigated in this study such as *R. claviger*, *C. orbicus*, *P. flava*, *T. incertus*, and *P. vittigera* were never collected at ACB throughout the study period (a single individual of *Hydropsyche* sp. was collected on one date). The biota at ACB is therefore clearly of a more lentic, than lotic, nature.

89. As discussed earlier in this report, the biota in the sand and gravel sediments of the heterogeneous dike fields was very similar to the macroinvertebrate community present in the high current erosional substrates of PCA. A similar comparison is apparent between the silt-bottomed areas of the dike field (especially at low flows) and the benthic community at ACB. *Chaoborus punctipennis* and *Limnodrilus* immatures, the dominant taxa in the slack waters of ACB, were also the two dominant taxa in mud substrates at DFT in the low flow period of September 1980 (Table 6) and at DFC in the low flow period of November 1979 (Table 4). *Ilyodrilus templetoni* and *Tanypus* sp., two other species common in the dike fields at low flow, were also quite abundant at ACB. *Limnodrilus hoffmeisteri*, one of the probable dominant taxa (along with *L. cervix*) among the *Limnodrilus* immatures present at ACB and the dike fields, has been characterized by Fomenko (1972) as a limnophile (preferring noncurrent water bodies) living in a limnobiotope (thick mud, noncurrent) habitat.

90. With decreased flows, the dike fields become isolated pools

with little or no current. They develop silty bottoms resulting from the deposition of previously suspended inorganic particles. In short, the dike fields become lakelike pools and the biotas reflect this change by showing an increased dominance of taxa common to lentic habitats such as ACB.

91. Sampling at DFT and DFL during the lowest flow period investigated (September 1980) provided a good example of current-substrate interactions, and the effect of these interactions on macroinvertebrate distribution. Low flow conditions created slack-water situations in parts of DFT. These areas were characterized by mud substrates and dominated by *Limnodrilus* immatures and *C. punctipennis*. In other words, the physical conditions in these parts of DFT were very similar to those encountered at ACB, and the resultant biotas were quite similar. The notch in dike 3 at DFT (Figure 6) resulted in water flow and a strong current in pool 3 of the dike field even at low flow, producing a sand and gravel substrate and colonization by *C. fluminea* and *R. claviger* (Table 6) in this erosional area (similar to the biota at PCA). At another dike field, DFL, mud substrates were dominated by *Limnodrilus* immatures at low flow. In contrast, sandy areas (which at this time were basically sand with a fine overlying layer of silt) were dominated by *Aulodrilus pigueti* (Table 5). Fomenko (1972) has shown *L. hoffmeisteri* to be most common in areas with a thick mud substrate; *A. pigueti*, however, is most common in substrates consisting of "slightly or moderately muddy sand" (Fomenko 1972). It is apparent from these and other examples that invertebrate distribution in the Mississippi River habitats is largely a function of current and substrate conditions, with current velocity a controlling factor in determining the nature of the substrate.

92. A relative lack of change in substrate composition at PCA, NBA, and ACB in comparison to the dike field habitats is clearly shown in Figure 15 and Table 3. Substrate dominance changed from an erosional substrate to a depositional substrate with decreased river stage for each of the dike fields. Substrace mapping of DFC for all three flow regimes (high, moderate, low) (Figures 12-14) also showed that the

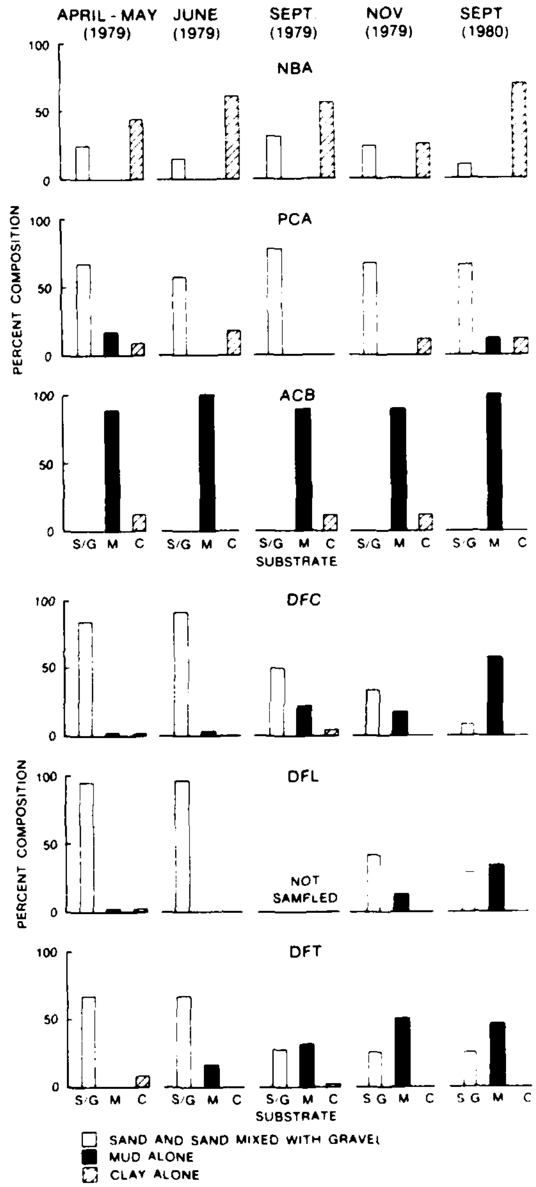


Figure 15. Percent composition of botton .ıbstrates for 1979-1980 study sice samplings. Only the three dominant substrate types are shown

mosaiclike nature of the dike field substrates continued for all flows but depositional substrates were much more prevalent at low flows (with a concomitant decrease in erosional substrates). These varying degrees of change in substrate at the study habitats over the different flow regimes closely paralleled the biotic changes as viewed in the ordinations.

93. The ordinational analyses of the various communities at the investigated habitats (Part IV--Results) showed that PCA, NBA, and ACB all remained dissimilar from each other for all flow regimes. It is apparent from the similarity matrices (Tables 11-15) that the communities in the high current conditions and basically sandy substrate of PCA were especially dissimilar from the biota found in the slack-water, silty substrate areas of ACB. It is also apparent that the benthos at PCA, NBA, and ACB have only minor changes in composition over flow regimes. That is, PCA is consistently dominated by sand-dwelling chironomids and *C. fluminea*; NBA is consistently dominated by the burrowing mayflies *T. incertus* and *P. vittigera* and hydropsychid caddisflies. Phantom midges, tubificid oligochaetes, and fingernail clams always dominate ACB. The dike fields, however, show large-scale changes in biotic composition with changes in river stage.

94. This change in biological affinities for the dike fields was apparent from a comparison of ordinations produced over the range of flows. While the positions of the dike fields in the ordinations at high and moderate flows were intermediate between PCA and ACB, both low flow ordinations showed marked similarities between the dike field communities and the biota at ACB (Figure 11). This shift in affinities was caused by a change in river stage with resulting changes in current and substrate conditions. At high and moderate flows the physically heterogeneous dike fields possessed some macroinvertebrate species found at PCA but also shared some species in common with ACB. With decreased river stage, current velocity decreased and the dike fields became largely a series of isolated slack-water pools. At this point, physical conditions "mimicked" conditions at ACB and the biota responded accordingly with a lentic assemblage of organisms dominating

the dike fields. This study indicates that the distribution of macroinvertebrates in the Lower Mississippi River habitats is a function of the physical characteristics of the system, notably current velocity and substrate composition.

PART VI: CONCLUSIONS

95. The permanent secondary channel (American Cutoff - PCA) was the least productive habitat in terms of macroinvertebrate densities among the habitats investigated. However, PCA was characterized by a distinct fauna, consisting of the sand-dwelling chironomids *Robackia claviger* and *Chernovskiia orbicus*, and the introduced clam species *Corbicula fluminea*.

96. The natural bank at Anconia (NBA), consisting largely of a clay substrate, was an optimal habitat for the large-river, burrowing mayflies *Tortopus incertus* and *Pentagenia vittigera*.

97. The abandoned channel at Matthews Bend (ACB) supported an assemblage of organisms (*Chaoborus punctipennis*, *Limnodrilus* spp., and *Sphaerium transversum*) characteristic of eutrophic lentic systems rather than riverine systems. This lentic community was present regardless of river stage, i.e. high flow on the Mississippi River did not result in a shift towards a biota more characteristic of lotic systems.

98. The habitat at ACB was very productive in terms of macroinvertebrate densities.

99. The dike field habitats were very heterogeneous both physically and biotically. Mud-bottom areas in the dike fields were generally productive and were dominated by tubificid oligochaetes. Sand-gravel areas were comparatively unproductive and were dominated by the animals that were most common in the high current conditions of PCA. Clay-bottomed areas in the dike fields (present at high to moderate flows) had a fauna similar to that found at NBA.

100. Unlike PCA, NBA, and ACB in which only minor changes in macroinvertebrate composition and substrate type occurred with changing river stage, the dike fields showed both marked community composition changes and changes in substrate dominance occurring with a shift from moderate to low flow conditions. With decreased flow, substrate dominance shifted from an erosional substrate (sand) to depositional (mud-silt). The biological communities also showed changes in affinities, becoming markedly similar to the lentic community at ACB during low flow conditions.

101. Changes in the physical structure of the dike field, such as notching the dike walls, results in changes in the dike field substrate composition and concomitantly changes the biotic composition. The notch in dike 3 at DFT maintained a strong current-sand substrate area that was colonized by *R. claviger* and *C. fluminea* even at low flows.

102. The macroinvertebrate composition and distributional patterns apparent at moderate flows in June and September 1979 in this study were in close agreement with the observations of the macroinvertebrate pilot study (Mathis et al. 1981) conducted at moderate flow in the summer of 1978.

103. In terms of macroinvertebrate distribution, the biotas in the Mississippi River habitats are a function of the physical attributes of that system, notably current and substrate.

PART VII: RECOMMENDATIONS

104. Although the macroinvertebrate densities at the natural bank habitat (NBA) were not as high as densities observed at ACB or in mud substrates of the dike fields at low flow, *Pentagenia vittigera* and *Tortopus incertus* (the two mayfly taxa which were numerically dominant in this habitat) are large macroinvertebrates and contribute appreciable biomass to the Mississippi River ecosystem. These species are of considerable biological interest since they colonize only large rivers and little is known of their life histories and habits. The effect on these species of covering natural bank areas with revetment is unknown, i.e. it is not known whether *P. vittigera* and *T. incertus* colonize banks under revetment structures. However, our study does show high densities of these animals in Mississippi River natural bank areas and the possible detrimental effects of covering more of their habitat with revetment material and/or altering current and substrate conditions in natural bank areas with dike structures should be a consideration in determining sites, materials, and extent of further river bank stabilization practices.

105. The dike fields proved to be areas of considerable physical and biotic heterogeneity at moderate and low flows. The dike fields' low flow, slack-water habitats were characterized by high macroinvertebrate densities, high species diversity, and habitat for species such as *Hexagenia* that require a depositional (mud) substrate. The channelization of the Lower Mississippi River and the cutting off of many of its meanders have resulted in a swift, channelized system with a decrease in slow-water, depositional substrate areas (Fremling 1973). Because the dike fields provide such areas, which are densely colonized at low flows, we recommend: (a) that the dike fields be designed such that they do not completely fill in, i.e. with moderate to low river stages slack-water pools should form below the dikes; and (b) that "notching" of dikes, which results in a strong current in the pools both above and below the notched dike, producing a sandy substrate, be discouraged. Such areas are, for macroinvertebrates, comparatively unproductive and

possess few taxa. The existence of such sandy areas has already been favored by channelization practices.

106. Abandoned channels provide a backwater habitat and, as shown in this study, are areas of high macroinvertebrate densities. In order to provide additional slow-water habitat to the Mississippi River system as a whole, and to aid free exchange between the river and the abandoned channels (both biotically and physically), we recommend that abandoned channels be kept open to the river, preferably at the downstream end of the channels.

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Table 1

Surface Acreage of Aquatic Habitats at Three River Stages from a Reach of the Lower Mississippi River, River Mile 480 to 530 AHP*

Habitat Type	Low Flow (18 Jun 76) Acres	%	Medium Flow (5 Dec 78) Acres	%	High Flow (18 Dec 78) Acres	%
Main channel	8,435	45	8,435	29	8,435	15
Natural banks	166	1	281	1	448	1
Revetted banks	842	5	1,536	5	1,791	3
Sandbar slack-water pools	101	1	0	0	0	0
Natural sandbars	962	5	2,397	8	6,285	11
Dike field pool areas	311	3	600	2	0	0
Dike field sandbars	848	5	7,393	26	10,441	18
Permanent secondary channels	530	2	630	2	630	1
Temporary secondary channels	706	4	990	3	2,553	5
Abandoned channel (Type I)	801	4	1,424	5	2,230	4
Abandoned channel (Type II)	1,860	9	1,860	7	1,860	3
Oxbow lakes	2,191	12	2,309	8	2,309	4
Borrow pits	826	4	1,165	4	4,798	8
Inundated floodplain	0	0	0	0	15,122	27
Totals	18,581	100	29,020	100	56,902	100
Average acres of habitat per river mile	372		580		1,138	

* This table was originally presented in Cobb and Clark (1981). AHP = Above Head of Passes.

Table 2

Summary of Sampling Scheme Employed in 1979-1980 Study of Lower Mississippi River Aquatic Habitats*

Site	Date	Flow Condition	Grab Type	Sampling Design	Sampling by Transect (T) or Depth (D)	Number of Grabs/ Station	Total Number of Grabs Taken	Pool Sampled (DF only)	Comments
DFC	4, 7, 8 May 1979	high	Shipek	Strat	T	1	48	A, 1, 2, 3	
	22, 24, 25 Jun 1979	moderate	Shipek	Strat	T	1	51	A, 1, 2, 3	
	26, 27 Sep 1979	moderate	Shipek	Syst	T	1	50	A, 1, 2, 3	
	6, 7 Nov 1979	low	PPN	Syst	T	1	49	A, 1, 2, 3	
	9 Sep 1980	low	PPN	Syst	T	2	48	1, 2, 3	A area not below water at this time
DFL	3, 4 May 1979	high	Shipek	Strat	T	1	42	A, 1, 2, 3	
	25, 29 Jun 1979	moderate	Shipek	Strat	T	1	48	A, 1, 2, 3	
	Sep 1979		(NOT SAMPLED)						
	5, 6, 7 Nov 1979	low	PPN	Syst	T	1	37	A, 1, 2, 3	
	10, 11 Sep 1980	low	Shipek/PPN	Syst	T	2	56	A, 1, 2, 3	Shipek used for 4 stations, PPN for 24
DFT	11 May 1979	high	Shipek	Syst	T	1	12	2, 3	Systematically sampled for all sampling periods
	28 Jun 1979	moderate	Shipek	Syst	T	1	12	2, 3	
	28 Sep 1979	moderate	Shipek	Syst	T	1	29	1, 2, 3	More grabs taken than previous samples due to increased number of sampling stations
	13 Nov 1979	low	PPN	Syst	T	1	28	1, 2, 3	
	16, 17 Sep 1980	low	PPN	Syst	T	2	48	1, 2, 3	
NBA	9 May 1979	high	Shipek	Syst	D	1	20		
	26 Jun 1979	moderate	Shipek	Syst	D	1	20		
	20, 24, 28 Sep 1979	moderate	Shipek	Syst	D	1	16		
	29 Nov 1979	low	Shipek	Syst	D	1	20		
	10 Sep 1980	low	Shipek	Syst	D	1	20		
PCA	10 May 1979	high	Shipek	Syst	T	2	24		
	19 Jun 1979	moderate	Shipek	Syst	T	2	24		
	20 Sep 1979	moderate	Shipek	Syst	T	2	18		
	8 Nov 1979	low	Shipek	Syst	T	2	18		
	10 Sep 1980	low	Shipek	Syst	T	1	9		
ACB	16, 17 Apr 1979	high	PPN	Syst	T	2	18		
	21, 22 Jun 1979	moderate	PPN	Syst	T	2	18		
	18 Sep 1979	moderate	PPN	Syst	T	2	18		
	8 Nov 1979	low	PPN	Syst	T	2	18		
	9 Sep 1980	low	PPN	Syst	T	2	18		

* PPN = Petite Ponar; Strat = stratified; Syst = systematic-transect; DF = dike field; A = above dike 1, 1 = pool below dike 1, 2 = pool below dike 2; 3 = pool below dike 3 (dikes numbered consecutively moving downstream).

Table 3

Breakdown (by Percent) of Substrate Composition at Sampling Sites

Substrate	April-May 1979 (High Flow)	June 1979 (Moderate Flow)	September 1979 (Moderate Flow)	November 1979 (Low Flow)	September 1980 (Low Flow)
		DFC			
Sand and gravel	38	32	31	12	4
Sand alone	46	59	18	22	4
Mud and gravel	--	--	6	6	--
Mud and sand	12	3	18	24	35
Mud, sand, and gravel	--	--	2	18	--
Mud alone	3	3	21	16	57
Clay alone	1	--	4	--	--
Clay and gravel	--	--	--	--	--
Clay and sand	1	2	--	--	--
Clay and mud	--	1	--	--	--
		DFL			
Sand and gravel	40	35	Not Sampled	32	7
Sand alone	55	61		9	21
Mud and gravel	--	--		12	--
Mud and sand	4	4		32	36
Mud, sand, and gravel	--	--		3	4
Mud alone	1	--		12	32
Clay alone	1	--		--	--
Clay and gravel	--	--		--	--
Clay and sand	--	--		--	--
Clay and mud	--	--		--	--

(Continued)

(Sheet 1 of 3)

Table 3 (Continued)

Substrate	April-May 1979 (High Flow)	June 1979 (Moderate Flow)	September 1979 (Moderate Flow)	November 1979 (Low Flow)	September 1980 (Low Flow)
		DFT			
Sand and gravel	--	--	11	11	4
Sand alone	67	67	17	14	21
Mud and gravel	--	--	--	--	--
Mud and sand	17	17	34	25	29
Mud, sand, and gravel	--	--	--	--	--
Mud alone	--	17	31	50	46
Clay alone	8	--	3	--	--
Clay and gravel	--	--	--	--	--
Clay and sand	--	--	3	--	--
Clay and mud	8	--	--	--	--
		NBA			
Sand and gravel	5	--	--	--	--
Sand alone	20	15	31	22	10
Mud and gravel	--	--	--	--	--
Mud and sand	--	5	--	--	--
Mud, sand, and gravel	--	--	--	--	--
Mud alone	--	--	--	--	--
Clay alone	45	60	56	28	70
Clay and gravel	--	--	6	--	--
Clay and sand	25	20	6	50	20
Clay and mud	5	--	--	--	--

(Continued)

Table 3 (Concluded)

Substrate	April-May 1979 (High Flow)	June 1979 (Moderate Flow)	September 1979 (Moderate Flow)	November 1979 (Low Flow)	September 1980 (Low Flow)
		PCA			
Sand and gravel	--	8	--	--	--
Sand alone	67	50	78	67	67
Mud and gravel	--	--	--	--	--
Mud and sand	8	17	11	22	11
Mud, sand, and gravel	--	--	--	--	--
Mud alone	17	--	--	--	11
Clay alone	8	17	--	11	11
Clay and gravel	--	--	--	--	--
Clay and sand	--	8	--	--	--
Clay and mud	--	--	11	--	--
		ACB			
Sand and gravel	--	--	--	--	--
Sand alone	--	--	--	--	--
Mud and gravel	--	--	--	--	--
Mud and sand	--	--	--	--	--
Mud, sand, and gravel	--	--	--	--	--
Mud alone	89	100	89	89	100
Clay alone	11	--	11	11	--
Clay and gravel	--	--	--	--	--
Clay and sand	--	--	--	--	--
Clay and mud	--	--	--	--	--

(Sheet 3 of 3)

Table 4

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for DFC*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
4, 7, 8 May 1979	116.5 (27)	680.6 (9)	NOT PRESENT
	Limnodrilus immatures	*Limnodrilus* immatures	
	Chernovskiia orbicus	*Limnodrilus cervix*	
22, 24, 25 Jun 1979	78.0 (28)	440.0 (12)	109.0 (4)
	Robackia claviger	*Limnodrilus* immatures	*Potamyia flava*
	Polypedilum sp.	*Pentagenia vittigera*	*Corbicula fluminea*
26, 27 Sep 1979	71.2 (18)	290.6 (19)	242.1 (1)
	Corbicula fluminea	*Limnodrilus* immatures	*Pentagenia vittigera*
	Robackia claviger	*Limnodrilus cervix*	*Limnodrilus cervix*
6, 7, Nov 1979	147.2 (12)	1328.6 (29)	NOT PRESENT
	Corbicula fluminea	*Limnodrilus* immatures	
	Limnodrilus immatures	*Chaoborus punctipennis*	
		Hexagenia sp.	
9 Sep 1980	484.3 (4)	2040.9 (39)	NOT PRESENT
	Polypedilum sp.	*Limnodrilus* immatures	
	Chironomus sp.	*Chironomus* sp.	

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 5

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for DFL*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
3, 4 May 1979	22.8 (36)	774.8 (1)	629.5 (1)
	Bezzia sp.	*Hydropsyche* sp.	*Hydropsyche* sp.
	Robackia claviger	*Lirceus* sp.	*Potamyia flava*
25, 29 Jun 1979	71.4 (20)	87.9 (8)	278.4 (2)
	Potamyia flava	*Limnodrilus* immatures	*Tortopus incertus*
	Robackia claviger	*Paracladopelma* sp.	*Lirceus* sp.
Sep 1979	NOT SAMPLED		
5, 6 Nov 1979	375.8 (11)	1671.2 (11)	NOT PRESENT
	Corbicula fluminea	*Limnodrilus* immatures	
	Limnodrilus immatures	*Chironomus* sp.	
10, 11 Sep 1980	2692.5 (13)	4518.6 (26)	NOT PRESENT
	Aulodrilus pigueti	*Limnodrilus* immatures	
	Limnodrilus immatures	*Tanypus* sp.	

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 6

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for DFT*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
11 May 1979	31.2 (7)	2653.4 (2)	48.4 (1)
	Limnodrilus immatures	*Limnodrilus* immatures	*Pentagenia vittigera*
	Chernovskiia orbicus	*Limnodrilus cervix*	
28 Jun 1979	101.0 (6)	2167.1 (4)	NOT PRESENT
	Limnodrilus immatures	*Limnodrilus* immatures	
	Pentagenia vittigera	*Limnodrilus hoffmeisteri*	
28 Sep 1979	48.4 (7)	924.0 (19)	290.6 (2)
	Chernovskiia orbicus	*Limnodrilus* immatures	*Tortopus incertus*
	Corbicula fluminea	*Limnodrilus cervix*	*Pentagenia vittigera*
13 Nov 1979	64.6 (4)	1299.8 (21)	NOT PRESENT
	Chernovskiia orbicus	*Limnodrilus* immatures	
	Chaoborus punctipennis	*Ilyodrilus templetoni*	
16, 17 Sep 1980	582.8 (11)	2805.6 (29)	NOT PRESENT
	Corbicula fluminea	*Limnodrilus* immatures	
	Robackia claviger	*Chaoborus punctipennis*	

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 7

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for NBA*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
5 May 1979	121.1 (3)	NOT PRESENT	62.2 (14)
	Pentagenia vittigera		*Pentageria vittigera*
	Crangonyx sp.		*Potamyia flava*
26 Jun 1979	12.1 (2)	NOT PRESENT	437.3 (16)
	Gammarus sp.		*Tortopus incertus*
			Hydropsyche sp.
20, 24, 28 Sep 1979	14.5 (5)	NOT PRESENT	349.9 (11)
	Pentagenia vittigera		*Pentageria vittigera*
	Tortopus incertus		*Tortopus incertus*
29 Nov 1979	42.4 (4)	NOT PRESENT	92.5 (11)
	Corophium sp.		*Pentageria vittigera*
	Corbicula fluminea		*Corophium* sp.
10 Sep 1980	375.3 (2)	NOT PRESENT	486.9 (18)
	Hydropsyche sp.		*Xenochironomus* sp.
	Potamyia flava		*Pentageria vittigera*

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 8

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for PCA*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
5 May 1979	9.2 (13)	52.5 (6)	24.2 (1)
	Chernovskiia orbicus	Lumbriculidae	*Hydropsyche* sp.
	Limnodrilus immatures	*Hydropsyche* sp.	
19 Jun 1979	19.1 (14)	72.6 (4)	58.1 (5)
	Robackia claviger	*Limnodrilus* immatures	*Tortopus incertus*
	Limnodrilus immatures	*Limnodrilus cervix*	*Potamyia flava*
20 Sep 1979	26.2 (13)	205.8 (2)	NOT PRESENT
	Robackia claviger	*Pentigenia vittigera*	
	Chernovskiia orbicus	*Corophium* sp.	
11 Nov 1979	37.5 (11)	66.6 (4)	36.3 (2)
	Chernovskiia orbicus	*Chaoborus punctipennis*	*Chaoborus punctipennis*
	Robackia claviger	*Limnodrilus* immatures	Nematoda
9 Sep 1980	116.9 (6)	133.2 (2)	217.9 (1)
	Corbicula fluminea	*Corophium* sp.	*Xenochironomus* sp.
	Chernovskiia orbicus	*Xenochironomus* sp.	*Pentagenia vittigera*

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 9

Dominant Taxa and Mean Macroinvertebrate Densities/Substrate Type for ACB*

Date	Sand and Gravel Mixed with Sand	Mud and Mud Mixed with Sand	Clay and Clay Mixed with Other Substrates
16, 17 Apr 1979	NOT PRESENT	6142.1 (15)	1226.9 (2)
		Limnodrilus immatures	*Limnodrilus* immatures
		Ilyodrilus templetoni	*Limnodrilus hoffmeisteri*
21, 22 Jun 1979	NOT PRESENT	3948.7 (18)	NOT PRESENT
		Chaoborus punctipennis	
		Limnodrilus immatures	
18 Sep 1979	NOT PRESENT	7243.3 (16)	3960.8 (2)
		Chaoborus punctipennis	*Chaoborus punctipennis*
		Limnodrilus immatures	*Glyptotendipes* sp.
8 Nov 1979	NOT PRESENT	5944.0 (14)	1593.0 (2)
		Chaoborus punctipennis	*Ilyodrilus templetoni*
		Limnodrilus immatures	*Limnodrilus* immatures
9 Sep 1980	NOT PRESENT	3111.6 (18)	NOT PRESENT
		Sphaerium transversum	
		Limnodrilus immatures	

* Numbers (not enclosed by parentheses) indicate mean densities per square metre for all macroinvertebrates collected in that substrate type. Number in parentheses indicates the number of samples from which this mean was computed. Below the means are listed the two most numerous taxa (most common listed above the second most common) collected in that substrate type for that sampling occasion. NOT PRESENT indicates that the particular substrate was not present (or only covered a very small area) at the time of sampling.

Table 10

Overall Numerically Dominant Taxa at the Study Sites for 1979-1980 Samplings*

Date	PCA	NBA	DFT
Apr-May 1979	Lumbriculidae (47) *Hydropsyche* sp. (21) *Chernovskiia orbicus* (11)	*Pentagenia vittigera* (50) *Potamyia flava* (13) *Lirceus* sp. (04)	*Limnodrilus* immatures (71) *Limnodrilus cervix* (10) *Ilyodrilus templetoni* (05)
June 1979	*Tortopus incertus* (21) *Limnodrilus* immatures (15) *Robackia claviger* (09)	*Tortopus incertus* (75) *Hydropsyche* sp. (08) *Pentagenia vittigera* (05)	*Limnodrilus* immatures (69) *Pentagenia vittigera* (10) *Limnodrilus hoffmeisteri* (07)
Sep 1979	*Pentagenia vittigera* (50) *Robackia claviger* (18) *Chernovskiia orbicus* (14)	*Pentagenia vittigera* (46) *Tortopus incertus* (25) *Corophium* sp. (04)	*Limnodrilus* immatures (45) *Limnodrilus cervix* (09) *Hexagenia* sp. (07)
Nov 1979	*Chernovskiia orbicus* (22) *Robackia claviger* (13) *Bezzia* sp. (13)	*Corophium* sp. (22) *Pentagenia vittigera* (18) Heptageniidae (16)	*Limnodrilus* immatures (50) *Ilyodrilus templetoni* (10) *Hexagenia* sp. (08)
Sep 1980	*Corbicula fluminea* (39) *Xenochironomus* sp. (17) *Corophium* sp. (15)	*Xenochironomus* sp. (38) *Pentagenia vittigera* (21) *Corbicula fluminea* (18)	*Limnodrilus* immatures (42) *Chaoborus punctipennis* (17) *Chironomus* sp. (07)

Date	DFL	DFC	ACB
Apr-May 1979	*Hydropsyche* sp. (27) *Potamyia flava* (13)** *Bezzia* sp. (13)	*Limnodrilus* immatures (66) *Limnodrilus cervix* (11)** *Ilyodrilus templetoni* (10)	*Limnodrilus* immatures (57) *Ilyodrilus templetoni* (27) *Limnodrilus hoffmeisteri* (06)
June 1979	*Potamyia flava* (22) *Tortopus incertus* (17)** *Limnodrilus* immatures (12)	*Limnodrilus* immatures (47) *Potamyia flava* (10)** *Robackia claviger* (08)	*Chaoborus punctipennis* (57) *Limnodrilus* immatures (19) *Sphaerium transversum* (05)
Sep 1979	NOT SAMPLED	*Limnodrilus* immatures (41) *Limnodrilus cervix* (15) *Corbicula fluminea* (15)	*Chaoborus punctipennis* (44) *Limnodrilus* immatures (13) *Glyptotendipes* sp. (04)
Nov 1979	*Limnodrilus* immatures (42) *Chironomus* sp. (15) *Corbicula fluminea* (15)	*Limnodrilus* immatures (68) *Hexagenia* sp. (07) *Corbicula fluminea* (06)	*Chaoborus punctipennis* (28) *Limnodrilus* immatures (21) *Ilyodrilus templetoni* (18)
Sep 1980	*Limnodrilus* immatures (24) *Aulodrilus pigueti* (19) *Tanypus* sp. (17)	*Limnodrilus* immatures (42) *Chironomus* sp. (15) *Tanypus* sp. (12)	*Sphaerium transversum* (35) *Limnodrilus* immatures (31) *Chaoborus punctipennis* (09)

* Numbers in parentheses indicate the percentage of all individuals collected at that site which belong to that particular taxon.

** Indicates those situations in which a stratified sampling design was employed.

Table 11

Similarity Matrix (Jaccard's Coefficient of Community) for Macroinvertebrate Communities Collected in April-May 1979

Study Sites	PCA	NBA	DFT	DFL	DFC	ACB
PCA	--	0.19	0.22	0.24	0.26	0.13
NBA	--	--	0.17	0.17	0.19	0.21
DFT	--	--	--	0.19	0.55	0.42
DFL	--	--	--	--	0.32	0.09
DFC	--	--	--	--	--	0.26
ACB	--	--	--	--	--	--

Table 12

Similarity Matrix (Jaccard's Coefficient of Community) for Macroinvertebrate Communities Collected in June 1979

Study Sites	PCA	NBA	DFT	DFL	DFC	ACB
PCA	--	0.15	0.19	0.38	0.28	0.15
NBA	--	--	0.28	0.31	0.30	0.20
DFT	--	--	--	0.38	0.47	0.25
DFL	--	--	--	--	0.46	0.16
DFC	--	--	--	--	--	0.20
ACB	--	--	--	--	--	--

Table 13

Similarity Matrix (Jaccard's Coefficient of Community) for Macroinvertebrate Communities Collected in September 1979

Study Sites	PCA	NBA	DFT	DFL	DFC	ACB
PCA	--	0.15	0.12	NS*	0.23	0.02
NBA	--	--	0.21	NS	0.26	0.12
DFT	--	--	--	NS	0.36	0.32
DFL	--	--	--	--	NS	NS
DFC	--	--	--	--	--	0.17
ACB	--	--	--	--	--	--

* NS = not sampled.

Table 14

Similarity Matrix (Jaccard's Coefficient of Community) for Macroinvertebrate Communities Collected in November 1979

Study Sites	PCA	NBA	DFT	DFL	DFC	ACB
PCA	--	0.19	0.22	0.23	0.17	0.11
NBA	--	--	0.10	0.17	0.15	0.05
DFT	--	--	--	0.57	0.38	0.48
DFL	--	--	--	--	0.41	0.32
DFC	--	--	--	--	--	0.30
ACB	--	--	--	--	--	--

Table 15

Similarity Matrix (Jaccard's Coefficient of Community) for Macroinvertebrate Communities Collected in September 1980

Study Sites	PCA	NBA	DFT	DFL	DFC	ACB
PCA	--	0.24	0.11	0.14	0.11	0.08
NBA	--	--	0.18	0.23	0.23	0.24
DFT	--	--	--	0.60	0.49	0.35
DFL	--	--	--	--	0.49	0.37
DFC	--	--	--	--	--	0.44
ACB	--	--	--	--	--	--

APPENDIX A: HABITAT TYPES IN THE LOWER MISSISSIPPI RIVER*

a. Main channel. That portion of the river encompassing the thalweg and navigation channel and lying riverward of the minus 10-ft LWRP contour on the convex bank and the toe (typically the minus 30-ft contour) of the natural or revetted bank on the concave bank. Environmental conditions in the main channel are rigorous with strong current velocities and turbulence, deep water, shifting coarse sand and gravel sediments, and high turbidity.

b. Natural banks. This habitat consists of the inundated natural or unprotected banks of the main and secondary channels, except where sandbars occur. Natural banks are located on the concave side of bendways and in straight reaches. Banks are steep (slope usually >30 percent) and are comprised of consolidated clays and silts (clay plug and backswamp deposits) of low plasticity often interspersed with sand layers or point bar deposits. Natural banks extend from the edge of the water to the floor of the channel, typically the minus 30-ft contour. Most natural banks continually cave and erode, but rates vary widely depending on hydraulic and geological conditions. Fallen trees and snags are generally present. Currents are strong, approaching adjacent main channel velocities, but turbulence caused by bank friction and bank line irregularities is high; upstream flow and eddies are common. The water is highly turbid as in the thalweg.

c. Revetted banks. This habitat consists of riverbanks that have been stabilized with articulated concrete mattress (ACM) and riprap. Revetments serve in conjunction with dikes to maintain a desired channel alignment. Revetted banks are most common on the concave side of bendways, but are also used to stabilize banks in other locations as needed. Some revetments may be 8 miles or more in length, while other structures are less than 1 mile long. Current velocities are similar to those of

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* The following descriptions of aquatic habitat types within the leveed Lower Mississippi River are taken from Cobb and Clark (1981).

the main channel, but flows are usually more streamlined than flows occurring along the more irregular natural banks. The concrete substrate and the interstices between the ACM and slabs constitute a unique environment for organisms in the river system. Coarse sand bed-load sediments from the main channel are often deposited on the lower part of the revetment, and finer suspended sediments may be found on the upper portions of a revetment, particularly in sheltered locations. Older revetments may be densely vegetated with willow and cottonwood stands and numerous species of herbs and forbs.

d. Sandbars and sandbar pools.

(1) Sandbars. Sandbars are relatively shallow habitats that gently slope toward the main channel and occur as point bars on the convex side of bendways, on the borders of large islands, and in channel crossings. Current velocities are moderate to swift and sediments are composed of coarse sand occasionally mixed with gravel. The minus 10-ft contour (LWRP) is the offshore boundary of the sandbar habitat. Turbid main channel waters occur in the sandbar habitat. Accretion stands of sandbar willows and cottonwoods are often found along the shoreline of bars.

(2) Sandbar pools. Slack-water pools are found in swales on large sandbars and middle islands. This habitat is formed as waters are ponded in depressions on a sandbar, following the receding of high waters. These pools assume lentic conditions and rapidly clear up as suspended materials settle.

e. Dike fields (including dike field pools and dike field sandbars). This habitat consists of the area influenced directly by the presence of impermeable stone dikes of various designs. Dikes generally extend perpendicularly from the bank line toward the main channel and are placed on point bars and across secondary channels. These structures are used to constrict and scour the navigation channel and to stabilize banks. Within the study reach, large limestone rocks are the material from which dikes are constructed. The dike field habitat is complex, consisting of a mixture of several riverine habitat types on a comparatively small scale; conditions change markedly with river stage. Typically, a dike field consists of a shallow to deep channel or pool area adjacent to the bank, the natural bank, and a large sandbar on the

channel side. The dike field pool may carry considerable flow when the river rises above the elevation of the dikes, but slackwater conditions are formed in the pool at low river stages (below the controlling elevation of the dikes). Current velocity may approach that of the adjacent main channel at peak flows. Sediments in the pool areas vary from coarse sands and gravel to fine unconsolidated silt-clay deposits in more sheltered areas. Sediment type may change with river stage due to the scouring action of the currents. Deep pools (plunge pools) are typically found on the immediate downstream side of dikes in the pool areas; water depths of a minus 40-ft LWRP or more may occur. Turbidity varies from that of main channel waters at high flows to low levels during pooled, lentic conditions. The sandbar associated with a dike field extends from the shoreline of the offshore bar to the border of the main channel (minus 10-ft LWRP contour). Environmental conditions are generally the same as for natural sandbars. The stone dikes themselves are a unique habitat within the river system for aquatic macroinvertebrates and other organisms. At high river stages, the entire dike field, including the sandbar and the pool area, is inundated and approximates main channel conditions.

f. Permanent secondary channels. This aquatic habitat is found where flow in the main channel is divided by a middle island or bar. The secondary channel is the smaller channel and is subordinate in flow-carrying capacity to the main channel. Flow is maintained year long. Environmental conditions are very similar to those of the main channel.

g. Temporary secondary channels. This habitat is similar to a permanent secondary channel, except that no flow occurs during low river stages and depths are generally shallower. Flow is blocked at the upstream opening of the channel by sand deposits. Dikes are sometimes placed across the upstream end of secondary channels to restrict flow.

h. Abandoned river channel (Type I). This habitat consists of relatively small old river channels located on the floodplain, which are formed by natural or man-made bendway cutoffs or other meandering actions of the river. Abandoned channels are distinguished from oxbow lakes primarily by their much smaller size. However, it is recognized

that both habitat types are formed by similar river action and are old river courses. This habitat remains confluent with the main channel via an outlet channel throughout most, if not all, of the year. The shoreward boundary of these areas was defined as 0-ft contour (LWRP). Lentic conditions exist in abandoned channels except when they are inundated during periods of overbank flow. Sediments are a flocculent silt-clay that may contain large amounts of detritus in the form of leaves and twigs. Water clarity is high compared to the turbid condition of the main channel and associated habitats. Average water depths are on the order of 15 to 20 ft.

i. Abandoned channel (Type II). This habitat is very similar physically to abandoned channel (Type I), except that the water body is not confluent with the main channel other than during periods of overbank flow and water depths are much shallower (<10 ft).

j. Oxbow lakes. Oxbow lakes are much larger than abandoned channel habitats (generally more than 1000 acres) and have much greater depths. The lakes are formed by the natural cutoff of large bendways or meander loops. Lentic conditions are characteristic and sediments are loosely consolidated silt-clays. Although oxbow lakes and abandoned channels have similar origins and are both old river courses, they are considered distinct habitats in an ecological sense.

k. Borrow pits. These man-made floodplain water bodies are formed by excavation of fill material for construction of levees. Borrow pits lie adjacent to the levee, primarily on the riverside, and vary greatly in size and depth. A typical borrow pit might be 175 ft wide and 1000 ft long and have an average depth of 6 ft. Lentic conditions prevail throughout the year, except when floodwaters inundate this habitat. Sediments are flocculent silt-clays.

l. Inundated floodplain. The terrestrial portion of the floodplain consists of various types of bottomland hardwood forests, old fields, and agricultural lands that are inundated during high flow periods.

APPENDIX B: SEDIMENT PARTICLE SIZE CLASSIFICATION*

Sediment-Substrate	Particle Size mm	U. S. Standard Sieve Series
Boulder	>256	
Rubble	64-256	
Coarse gravel	32-64	
Medium gravel	8-32	
Fine gravel	2-8	10
Coarse sand	0.5-2	35
Medium sand	0.25-0.5	120
Fine sand	0.125-0.25	230
Very fine sand	0.0625-0.125	
Silt-mud	0.0039-0.0625	
Clay	<0.0039	

* This table was adapted from a soil particle size classification scheme presented by the U. S. Environmental Protection Agency (1973).

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Benthic macroinvertebrates of selected aquatic habitats of the Lower Mississippi River / by David C. Beckett ... [et al.] (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1983.

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1. Aquatic animals. 2. Benthos. 3. Invertebrates. 4. Mississippi River. I. Beckett, David C. II. United

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